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Part 2: Spatial Audio Object Coding (SAOC)

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Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 29, *Coding of audio, picture, multimedia and hypermedia information*.

This second edition cancels and replaces the first edition (ISO/IEC 23003-2:2010), which has been technically revised. It also incorporates the Amendments ISO/IEC 23003-2:2010/Amd 1:2015, ISO/IEC 23003-2:2010/Amd 2:2015, ISO/IEC 23003-2:2010/Amd 3:2015, ISO/IEC 23003-2:2010/Amd 4:2016 and ISO/IEC 23003-2:2010/Amd 5:2016 and the Technical Corrigenda ISO/IEC 23003-2:2010/Cor 1:2012 and ISO/IEC 23003-2:2010/Cor 2:2014.

The main changes compared to the previous edition are as follows:

— clarifications on SAOC-DE profile description;

— corrections to SAOC-DE profile specification;

— corrections to SAOC-DE profile;

— corrections to MPEG SAOC IS text;

— corrections to the low power mode.

A list of all parts in the ISO/IEC 23003 series can be found on the ISO website.

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Introduction

In the preferred modes of operating, the SAOC system, the transmitted signal can be either mono, stereo or 3-channel. The audio objects can be represented by a mono, stereo, or 3-channel signal or have the MPEG surround (MPS) multi-channel background object (MBO) format. The additional parametric data exhibits a significantly lower data rate than required for transmitting all objects individually, making the coding very efficient. At the same time, this ensures compatibility of the transmitted signal with legacy devices.

When a multi-channel rendering setup (e.g. a 5.1 loudspeaker setup) is required, the SAOC system acts as a transcoder, converting the additional parametric data to MPS parameters, and interfaces to the MPS decoder that acts as rendering device. For certain rendering setups (e.g. a binaural or plain stereo setup), the SAOC system behaves as a decoder, using its own rendering engine. Another key feature is that the SAOC parametric data from different streams can be merged at parameter level to allow for the combination of SAOC streams, similar to the functionality of a multi-point control unit (MCU).

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Information technology — MPEG audio technologies — Part 2: Spatial Audio Object Coding (SAOC)

1 Scope

This document specifies the reference model of the spatial audio object coding (SAOC) technology that is capable of recreating, modifying and rendering a number of audio objects based on a smaller number of transmitted channels and additional parametric data.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 23003-1:2007, *Information technology — MPEG audio technologies — Part 1: MPEG Surround*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
audio object
input audio signal consisting of one, two or multiple channels, including multi-channel background object (MBO)

3.2
frame
time segment (3.15) to which SAOC processing is applied according to the data conveyed in the corresponding SAOCFrame() or SAOCDEFrame() syntax elements

3.3
hybrid filterbank
structure consisting of a quadrature mirror filter (QMF) bank and oddly modulated Nyquist filter banks, used to transform time domain signals into *hybrid subband* (3.5) samples

3.4
hybrid filtering
filtering step on a quadrature mirror filter (QMF) subband signal resulting in multiple *hybrid subbands* (3.5)

Note 1 to entry: The resulting hybrid subbands can be non-consecutive in frequency.

3.5
hybrid subband
subband obtained after *hybrid filtering* (3.4) of a quadrature mirror filter (QMF) subband

Note 1 to entry: The hybrid subband can have the same time/frequency resolution as a QMF subband.

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3.6
input channel
input audio channel corresponding to the channels of an *audio object* (3.1)

3.7
output channel
audio channel corresponding to a specific speaker

Note 1 to entry: Channel abbreviations and loudspeaker positions are given in Table 1.

3.8
parameter band
one or more *hybrid subbands* (3.5) applicable to one parameter

3.9
parameter time slot
specific *time slot* (3.16) for which the parameter is defined

3.10
parameter set
parameters associated with a specific *parameter time slot* (3.9)

3.11
parameter subset
parameters associated with a specific *parameter time slot* (3.9) and a specific one-to-two (OTT) box or two-to-three (TTT) box

3.12
processing band
one or more *hybrid subbands* (3.5) defining the finest frequency resolution that could be controlled by the parameters

3.13
QMF bank
bank of complex exponentially modulated filters

3.14
QMF subband
subband obtained after QMF filtering of a time-domain signal, without any additional hybrid filtering stage

3.15
time segment
group of consecutive *time slots* (3.16)

3.16
time slot
finest resolution in time for spatial *audio object* (3.1) coding (SAOC) time borders

Note 1 to entry: One time slot equals one subsample in the hybrid quadrature mirror filter (QMF) domain.

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4 Notations and abbreviated terms

4.1 Notation

The description of the SAOC system uses the following notations:

— vectors are indicated by bold lower-case names, e.g. **vector**;

— matrices (and vectors of vectors) are indicated by bold upper-case single letter names, e.g. **M**;

— variables are indicated by italic, e.g. *variable*;

— functions are indicated as *func(x)*.

For equations (and flowcharts), normal mathematical (and pseudo-code) interpretation is assumed with no rounding or truncation unless explicitly stated.

4.2 Operations

4.2.1 Scalar operations

x^*	is the complex conjugate of x.
$y = \log_{10}(x)$	is the base-10 logarithm of x.
$y = \min(...,...)$	is the minimum value in the argument list.
$y = \max(...,...)$	is the maximum value in the argument list.
$\exp(x)$	is the exponential function of x.

4.2.2 Vector and matrix operations

$\mathbf{m} = diag(\mathbf{M})$	is main diagonal of matrix, **M**.
$\mathbf{y} = sort(\mathbf{x})$	is equal to the sorted vector **x**, where the elements of **x** are sorted in ascending order.
$y = trace(\mathbf{M})$	is sum of all diagonal elements of matrix, **M**.
$\mathbf{M}^*$	is the complex conjugate transpose of **M**.

4.3 Constants

ε	is a constant to avoid division by and logarithm of zero, e.g. $\varepsilon = 10^{-9}$.
$\mathbf{0}_{A \times B}$	is a matrix of size $A \times B$ consisting of zeros.
$\mathbf{I}_A$	is an identity matrix of size $A \times A$.

4.4 Variables

$a_{i,y}^{l,m}$	is the virtual speaker transfer function, defined for binaural output channel, i, audio object, y, and all parameter time slots, l, and processing bands, m.
D	is the downmix matrix.

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$\mathbf{D}_{CLD}$	is the three-dimensional matrix holding the dequantized, and mapped CLD data for every OTT box, every parameter set and M_{proc} bands.
$\mathbf{D}_{ICC}$	is the three-dimensional matrix holding the dequantized, and mapped ICC data for every OTT or TTT box, every parameter set and M_{proc} bands.
$\mathbf{D}_{CPC\_1}$, $\mathbf{D}_{CPC\_2}$	are the three-dimensional matrices holding the dequantized, and mapped first and second CPC data for every TTT box, every parameter set and M_{proc} bands.
$\mathbf{D}_{CLD\_1}$, $\mathbf{D}_{CLD\_2}$	are the three-dimensional matrices holding the dequantized, and mapped first and second CLD data for every TTT box, every parameter set and M_{proc} bands.
$\mathbf{D}_{DCLD}$	is the matrix holding the dequantized, and mapped DCLD data for every input channel and every parameter set.
$\mathbf{D}_{DMG}$	is the matrix holding the dequantized, and mapped DMG data for every input channel and every parameter set. If DMG data contains information for more than one downmix channel, $\mathbf{D}_{DMG}$ is a three-dimensional matrix holding the dequantized, and mapped DMG data for every input channel, every downmix channel and every parameter set.
$\mathbf{D}_{IOC}$	is the four-dimensional matrix holding the dequantized, and mapped IOC data for every input channel pair, every parameter set and M_{proc} bands.
$\mathbf{D}_{NRG}$	is the two-dimensional matrix holding the dequantized, and mapped NRG data for the highest energy within every parameter set and M_{proc} bands.
$\mathbf{D}_{OLD}$	is the three-dimensional matrix holding the dequantized, and mapped OLD data for every input channel, every parameter set and M_{proc} bands.
$\mathbf{D}_{PDG}$	is the three-dimensional matrix holding the dequantized, and mapped PDG data for every downmix channel, every parameter set and M_{proc} bands.
$\mathbf{D}_{BGO}$	is the downmix sub-matrix for BGOs.
$\mathbf{D}_{FGO}$	is the downmix sub-matrix for FGOs.
$H^{m}_{i,\{L,R\}}$	is the HRTF parameter which represents the average level with respect to the left and right ear $\{L, R\}$ for the HRTF database index i, and all processing bands m.
idx*XXX*(...,...)	is a three-dimensional matrix holding the Huffman, and delta decoded indices. *XXX* can be any of OLD, IOC, NRG, DCLD, DMG, PDG.
K	is the number of hybrid subbands.
L	is the number of parameter sets.
M	is the number of downmix channels.
M_{proc}	is the number of processing bands.
M_{QMF}	is the number of QMF subbands depending on sampling frequency.

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$\mathbf{M}^{l,m}$	is the OTN/TTN upmix matrix for the prediction mode of operation.
$\mathbf{M}_{\text{Energy}}^{l,m}$	is the OTN/TTN upmix matrix for the energy mode of operation.
$\mathbf{M}_1^{n,k}$, $\mathbf{M}_2^{n,k}$	are the time and frequency variant pre-matrices, defined for all time slots, *n*, and all hybrid subbands, *k*.
$\mathbf{M}_{\text{ren}}^{l,m}$	is the time and frequency variant rendering matrix, defined for all parameter time slots, *l*, and all processing bands, *m*.
$\mathbf{G}_{\text{DE}}^{l,m}$	is the time and frequency variant parametric processing matrix, defined for all parameter time slots, *l*, and all processing bands, *m*.
$\mathbf{M}_{\text{DE}}^{l,m}$	is the time and frequency variant residual processing matrix, defined for all parameter time slots, *l*, and all processing bands, *m*.
m_{BGO}	is the modification gain for BGOs.
m_{FGO}	is the modification gain for FGOs.
m_{G}	is the decoder limited modification gain.
m_{G}^{input}	is the input modification gain.
N	is the number of SAOC input channels of audio objects.
N_{FGO}	is the number of FGOs.
N_{EAO}	is the number of EAO channels.
N_{MPS}	is the number of MPS output channels.
N_{HRTF}	is the number of different HRTFs in the HRTF database.
N_{g}	is the number of groups of downmix signals.
N_{g}^{q}	is the number of downmix signals assigned to group $\mathbf{g}_q$, defined for all group indices, *q*.
$\mathbf{g}_q$	is a vector with the indices of the downmix signals assigned to the same group, defined for all group indices, *q*.
P	is the frame length.
$\mathbf{W}_{\text{ADG}}^{l,m}$	is the time and frequency variant matrix including ADGs, defined for all parameter time slots, *l*, and all processing bands, *m*.
$\mathbf{W}_h^{l,m}$	is the time and frequency variant sub-rendering matrix, defined for OTT box, *h*, (of the MPS "5-1-5" tree-structure), all parameter time slots, *l*, and all processing bands, *m*.

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$\mathbf{W}_{\mathrm{PDG}}^{l,m}$ is the time and frequency variant matrix including PDGs, defined for all parameter time slots, *l*, and all processing bands, *m*.

$\mathbf{s}^{n,k}$ is a vector with the hybrid subband (encoder) input channels, defined for all time slots, *n*, and all hybrid subbands, *k*.

$\mathbf{x}^{n,k}$ is a vector with the hybrid subband (transcoder/decoder) input signals (downmix and residuals), defined for all time slots, *n*, and all hybrid subbands, *k*.

$\mathbf{y}^{n,k}$ is a vector with the (transcoder/decoder) output hybrid subband signals, which are fed into the hybrid synthesis filter banks, defined for all time slots, *n*, and all hybrid subbands, *k*.

ϕ_i^m is the HRTFs parametric representation of the average phase difference, defined for the HRTF database index, *i*, and all processing bands, *m*.

4.5 Abbreviated terms

ADG arbitrary downmix gain

BGO background object

CLD channel level difference; describes the energy difference between two channels

CPC channel prediction coefficient; used for recreating three or more channels from two channels

DCLD downmix channel level difference; describes the gain differences of objects contributing to the left and right downmix channel in case of a stereo downmix

DCU distortion control unit

DE dialogue enhancement

DMG downmix gain; gains applied to each object before downmixing

EAO enhanced audio object

FGO foreground object

HRTF head related transfer function

ICC inter channel correlation; describes the correlation between two channels

IOC inter object correlation; describes the correlation between two channels of audio objects

LD low delay

MBO multi-channel background object

MCU multi-point control unit

MPS mpeg surround

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N/A not applicable

NRG absolute object energy; specifies the absolute energy of the object with the highest energy for the corresponding parameter band

OLD object level difference, describes intensity differences between one object and the object with the highest energy for the corresponding parameter band

OTN conceptual “One-To-N” unit that takes one channel as input and produces N channels as output

OTT conceptual “One-To-Two” unit that takes one channel as input and produces two channels as output

PDG post(processing) downmix gains; describes intensity differences between the encoder-generated downmix and the post(processed) downmix for the corresponding parameter band

QMF quadrature mirror filter

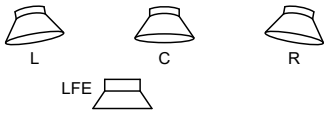
SAC spatial audio coding

SAOC spatial audio object coding

TTN conceptual "Two-To-N" unit that takes two channels as input and produces N channels as output

TTT conceptual "Two-To-Three" unit that takes two channels as input and produces three channels as output

Table 1 — Channel abbreviations and loudspeaker positions

Channel abbreviation	Loudspeaker position	Figure
L	Left front	
R	Right front	
C	Center front	
LFE	Low frequency enhancement	
Ls	Left surround	
Rs	Right surround	

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5 SAOC overview

5.1 General

Spatial audio object coding (SAOC) is a parametric multiple object coding technique. It is designed to transmit a number of audio objects in an audio signal that comprises *M* channels. Together with this backwards compatible downmix signal, object parameters are transmitted that allow for recreation and manipulation of the original object signals. An SAOC encoder produces a downmix of the object signals at its input and extracts these object parameters. The number of objects that can be handled is in principle not limited.

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The object parameters are quantized and coded efficiently into an SAOC bitstream.

The downmix signal can be compressed and transmitted without the need to update existing coders and infrastructures. The object parameters, or SAOC side information, are transmitted in a low bitrate side channel, e.g. the ancillary data portion of the downmix bitstream.

On the decoder side, the input objects are reconstructed and at the same time rendered to a certain number of playback channels. The rendering information containing reproduction level and panning position for each object is user supplied or can be extracted from the SAOC bitsream (e.g. preset information). The rendering information can be time variant. Output scenarios can range from mono to multi-channel (e.g. 5.1) and are independent from both, the number of input objects and the number of downmix channels. Binaural rendering of objects is possible including azimuth and elevation of virtual object positions. An optional effects interface allows for advanced manipulation of object signals, besides level and panning modification.

The objects themselves can be mono signals, stereophonic signals, as well as multi-channel signals (e.g. 5.1 channels). Typical downmix configurations are mono and stereo.

5.2 Basic structure of the SAOC transcoder/decoder

The SAOC transcoder/decoder module described below may act either as a stand-alone decoder or as a transcoder from an SAOC to an MPS bitstream, depending on the intended output channel configuration. Table 2 illustrates the differences between the two modes of operation.

Table 2 — Operation modes of the SAOC

Output signal configuration	# of output channels	# of input channels	SAOC module mode	SAOC module output	MPS decoder required
Mono/stereo/binaural/ 3-channel configuration	1, 2 or 3	1, 2 or 3	Decoder	PCM output	No
Multi-channel configuration	>2	1 or 2	Transcoder	MPS bitstream, downmix signal	Yes

Figure 1 shows the basic structure of the SAOC transcoder/decoder architecture. The residual processor extracts the EAOs from the incoming downmix using the residual information contained in the SAOC bitstream. The downmix pre-processor processes the regular audio objects. The EAOs and processed regular audio objects are combined to the output signal for the SAOC decoder mode or to the MPS downmix signal for the SAOC transcoder mode. The detailed descriptions of these processing blocks are given in the corresponding subclauses, namely, 7.5 and 7.5.4, which describe the SAOC transcoder/decoder functionality and 7.6 explains handling of enhanced audio objects and residual processing.

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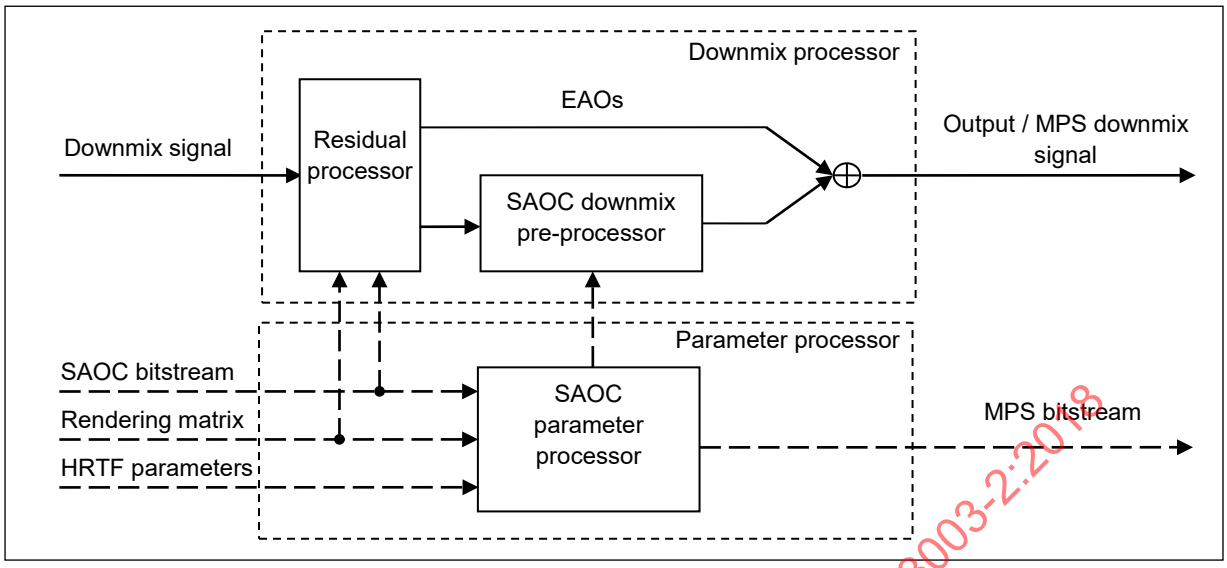

Figure 1 — Overall structure of the SAOC transcoder/decoder architecture

Figure 2 (left) shows a block diagram of an SAOC transcoder unit. It consists of an SAOC parameter processor and a downmix processor module. The SAOC parameter processor decodes the SAOC bitstream and has furthermore a user interface from which it receives additional input in form of generally time variant rendering information. It provides steering information for the downmix processor. The SAOC transcoder outputs an MPS bitstream and downmix signal, as an input to the MPS decoder. In case of a mono downmix, the downmix pre-processor leaves the downmix signal unchanged. However, in case of a stereo downmix, it is functional to pre-process the downmix signal to allow more flexible object panning than is supported by the MPS rendering engine alone. In case of a mono/stereo/binaural/multi-channel output configuration, the SAOC system works in decoder mode and MPS decoding is omitted [see Figure 2 (right)]. Here, the downmix processing module directly provides the output signal.

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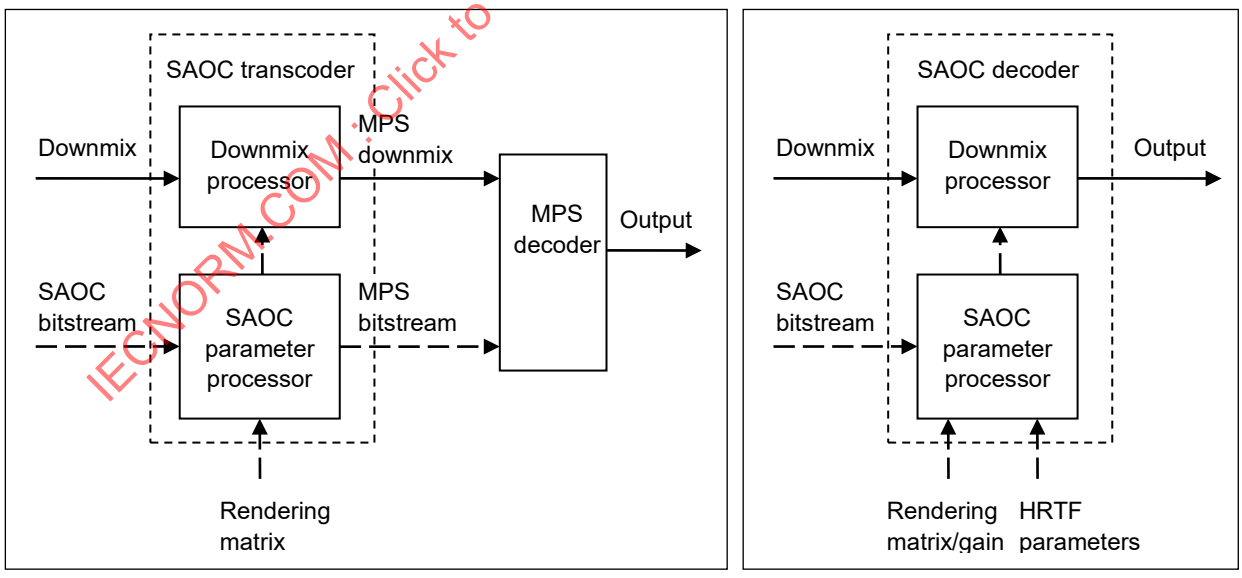

Figure 2 — Block diagrams of the SAOC transcoder (left) and decoder (right) processing modes

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5.3 Tools and functionality

5.3.1 General SAOC tools

5.3.1.1 Overview

The SAOC system incorporates a number of tools that allow for flexible complexity and/or quality trade-off, as well as a diverse set of functionality. In the following subclauses, some key-features of SAOC are briefly outlined.

5.3.1.2 Binaural decoding

The SAOC system can be operated in a binaural mode. This enables a multi-channel impression over headphones by means of head related transfer function (HRTF) filtering.

5.3.1.3 Efficient multipoint control unit support

In order to use the SAOC concept for teleconferencing applications, a multipoint control unit (MCU) functionality of combining the signals of several communication partners without decoding/re-encoding the corresponding audio objects is provided. The MCU combines the input SAOC side information streams into one common SAOC bitstream in a way that the parameters representing all audio objects from the input bitstreams are included in the resulting output bitstream. These calculations are performed in the parameter domain without the need to analyse the downmix signals and, therefore, introduce no additional delay in the signal processing chain.

5.3.1.4 External downmix

The SAOC system is capable of handling not only encoder-generated downmixes but also post(processed) downmixes supplied to the encoder in addition to the input audio object signals. In this case, post downmix gains (PDGs) are calculated in the encoder and conveyed as a part of the SAOC bitstream. The difference of the downmix signals is compensated for at the SAOC decoder side.

5.3.1.5 Multichannel background object

The audio input to a SAOC encoder can contain a so-called multi-channel background object (MBO). Generally, the MBO can be considered as a complex sound scene involving a large and often unknown number of sound sources, for which no controllable rendering functionality is required. The MBO is represented by a downmix of the MPS encoded complex sound scene and corresponding MPS parameters.

5.3.1.6 Enhanced audio object processing

A special "Karaoke-type" application scenario requires a total suppression of specific objects, typically the lead vocals, while keeping the perceptual quality of the background sound scene unharmed. High sound quality is assured by the incorporation of residual coding enabling a better separation of the background object and foreground objects. The EAO processing mode supports reproduction of both EAO and regular objects exclusively and arbitrary mixtures of these object groups.

5.3.1.7 Distortion control unit

The distortion control unit is incorporated into the SAOC system in order to provide a flexible control for users and audio content providers over the SAOC rendering functionality and audio output quality.

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5.3.1.8 Predefined rendering information

The SAOC system is capable of starting playback with some initial predefined settings which can be stored and/or transmitted in SAOC bitstream. These settings can be dynamically updated. The SAOC system allows instantaneous switching between them if more than one set of predefined settings is available.

5.3.1.9 Effects interface

The SAOC effects interface operates on the downmix and therefore is part of the downmix processor of the SAOC transcoder or decoder. The effects interface allows objects or linear combinations of objects to be extracted from the downmix for effects processing. There are two types of effects processing interfaces. The first type, referred to as the insert effects interface, allows effects processing to individual objects in the downmix. The second type, referred to as the send effects interface, allows effect processing on individual objects or linear combinations thereof.

5.3.2 High quality, low power and low delay

The SAOC decoder can be implemented in a high quality (HQ) version, a low power (LP) version and a low delay (LD) version. The main differences are outlined by Table 3 and given in detail in 7.13 and 7.14.

Table 3 — Outline of difference between the HQ, LP and LD SAOC system

Tool or functionality	HQ system	LP system	LD system
Filterbank	Complex valued QMF	Partially complex valued QMF	LD QMF, no Nyquist filterbank
Aliasing reduction	Not applicable	Tool operates on the real-valued part of the frequency range	Not applicable
Residual coding	Supported over the entire frequency range	Only supported over the complex valued part of the frequency range	Not supported
Decorrelators	Supported	Not supported for stereo downmix	Supported

5.4 Delay and synchronization

5.4.1 Overview

The SAOC decoder introduces a delay when processing the time domain signal coming from a downmix decoder. Depending on whether the SAOC module is working as a decoder or as a transcoder for a multichannel renderer (MC-SAOC), i.e. MPS decoder, two different cases are to be taken into account.

For all the different cases described in this subclause, the transmission of the SAOC side information with respect to the transmission of the coded downmix signal is done in such a manner that there is no need to further delay the downmix signal before the SAOC processing. This means that synchronization of the spatial data and downmix is achieved at the SAOC decoder/transcoder, following the temporal relationships described in Clause 8.

5.4.2 High quality and low power processing

5.4.2.1 SAOC decoding mode

The SAOC decoder (mono, stereo, 3-channel or binaural up-mix modes) introduces a total delay of 1 281 time domain samples for the high quality (HQ) mode and 1 601 samples for the low power (LP)

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mode. As shown in Figure 3, the analysis filterbank as outlined in 7.3 introduces a delay of 704 samples, while the synthesis filterbank introduces 257 for HQ and 577 for LP. The analysis filterbank processing delay consists of the QMF and hybrid processing delays, 320 and 384 time domain samples, respectively. If no real to complex conversion is performed, it shall be replaced by a delay line. This leads to 320 time samples which are added on top the analysis processing delay for both HQ and LP decoders. The synthesis filterbank introduces 257 samples delay which is introduced by the QMF synthesis filtering. The hybrid synthesis does not introduce further delay. For the LP decoder, the complex to real conversion adds 320 time domain samples to the synthesis processing delay.

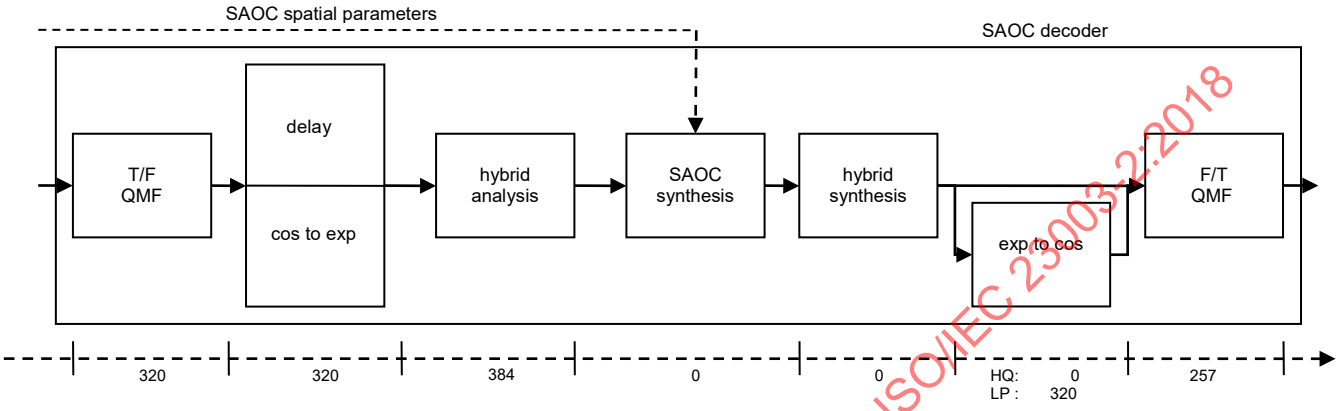

Figure 3 — Delay for the different parts of the SAOC decoder

5.4.2.2 SAOC transcoding mode

The MPS renderer introduces a delay when processing the downmix from the SAOC transcoder. Two cases may be distinguished: mono and stereo downmix.

In case of a mono downmix, the signal from the downmix decoder is passed directly to the MPS decoder as no further processing is applied to the downmix, as depicted in Figure 4. The MC-SAOC processing delay shall be equal to the one given by the SAOC decoder, as the SAOC to MPS parameter processing does not introduce any additional delay.

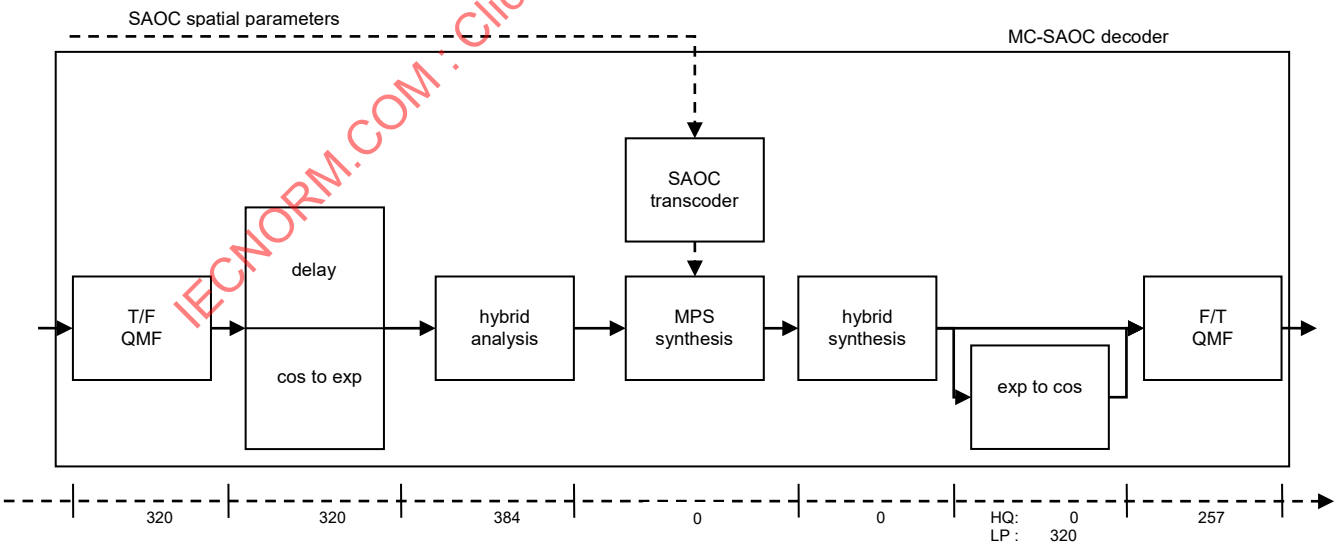

Figure 4 — Delay for the different parts of the MC-SAOC decoder with mono downmix signal

In case of a stereo downmix, the SAOC transcoder processes the core coder signal to adapt it to the subsequent MPS decoding, as shown in Figure 5. The delay of the MPS renderer shall be added on top of the SAOC processing delay. Both the SAOC transcoder and the MPS decoder introduce a delay of

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1 281 samples for the HQ mode or of 1 601 samples for the LP mode. Their analysis/synthesis delay is distributed as described above for the SAOC decoder.

If both modules are not integrated, i.e. they interface via the time domain, the total processing delay shall be the sum of the delays introduced by each module plus buffering needed for synchronization of the MPS parameters to the downmix.

The size of buffer B (spatial parameters buffer) is a multiple of the frame length. The downmix buffer A is needed to synchronize the delayed bitstream and processed downmix. To achieve synchronization, Formula (1) should be met; both buffer sizes are given in time domain samples:

$$B = N*\text{Frame length so that } B \geq 1\,281 \text{ (HQ) or } B \geq 1\,601 \text{ (LP); } N=0,1,2,3,\ldots. \quad (1)$$

$$A(HQ) = B - 1281 \text{ or } A(LP) = B - 1\,601$$

Given an interface via the hybrid QMF domain, the overall processing delay of the multi-channel rendering is equal to the delay of the SAOC decoding mode.

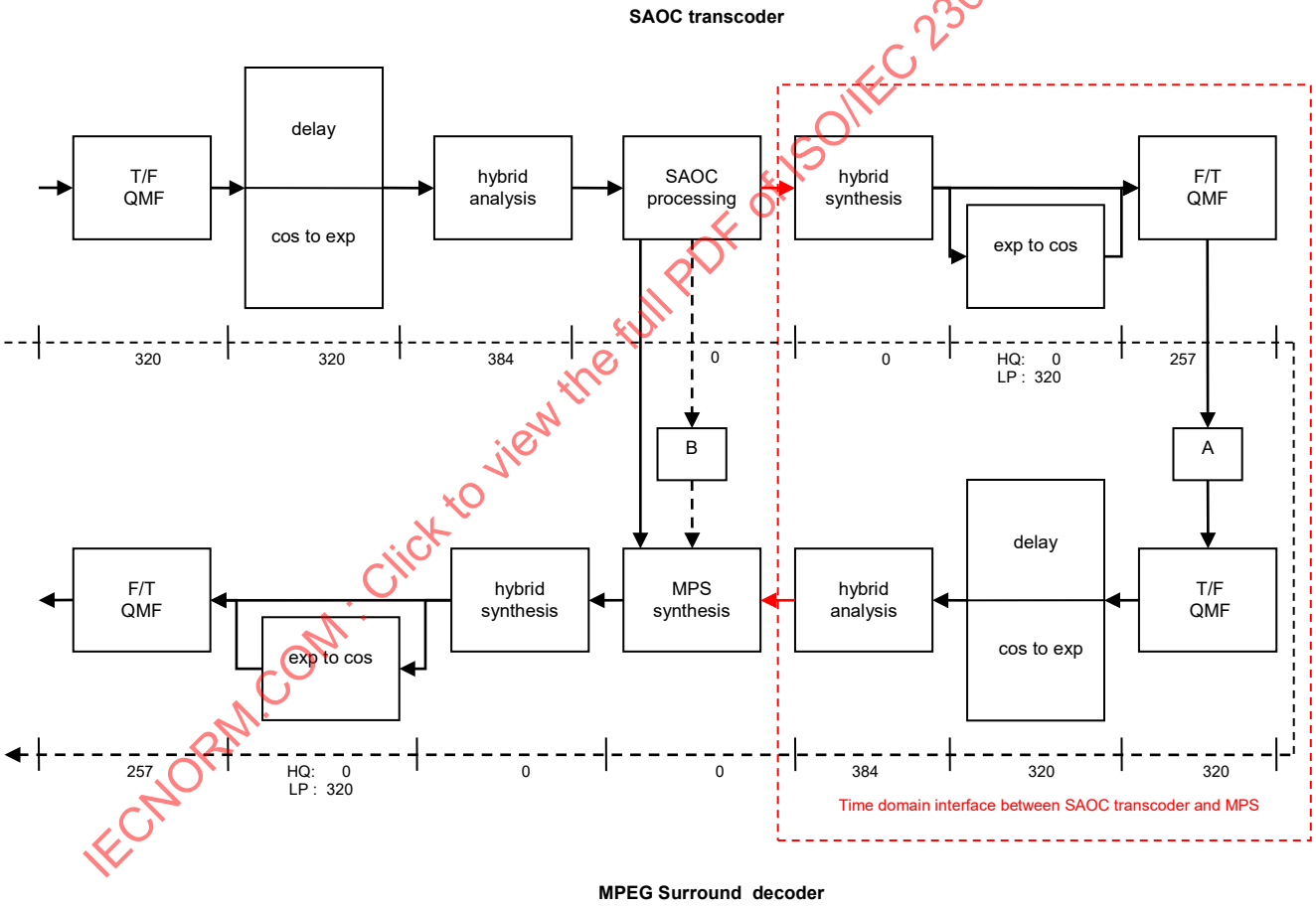

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Figure 5 — Delay for the different parts of the MC-SAOC decoder with stereo downmix signal

5.4.2.3 Connection to an arbitrary core coder

If the (MC-)SAOC decoder is connected with an arbitrary downmix coder (including HE-AAC) via the time domain, as shown in Figure 6, the additional delay introduced by the (MC-)SAOC decoder processing is described in the previous subclauses.

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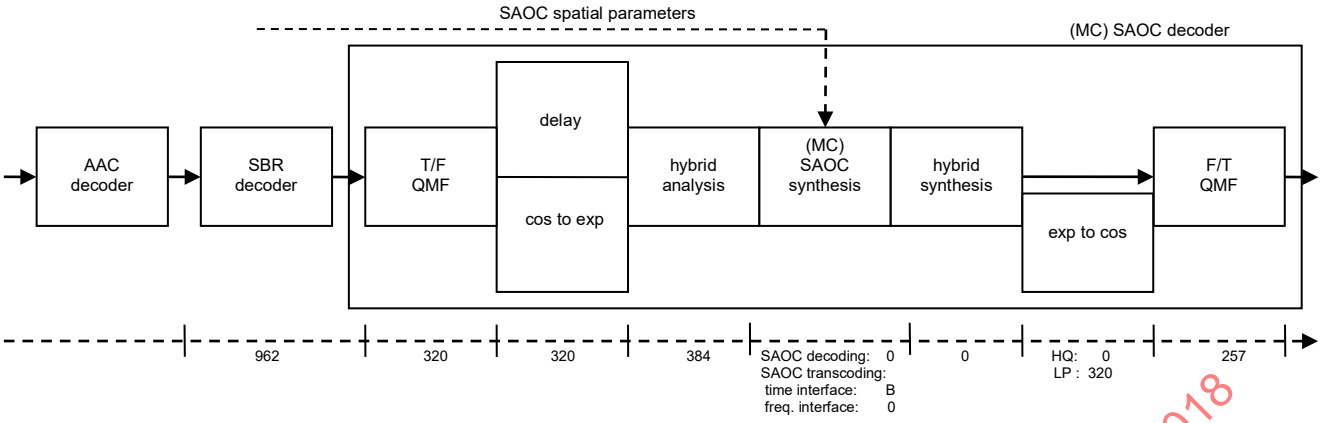

Figure 6 — Delay when connecting (MC-)SAOC in the time-domain for an arbitrary core codec (including HE-AAC)

If the (MC-)SAOC decoder is directly connected with a High Efficiency AAC decoder via the QMF domain, as shown in Figure 7, the delay shall be reduced as outlined in ISO/IEC 23003-1:2007, 4.5 for a MPS decoder. The only additional delay is introduced by the real to complex converter for a LP decoder or the delay compensation for a HQ decoder. No hybrid analysis delay is introduced due to the fact that the look-ahead of 384 time domain samples is already available on the SBR tool of HE-AAC, as described in ISO/IEC 14496-3:2009, 8.A.3.

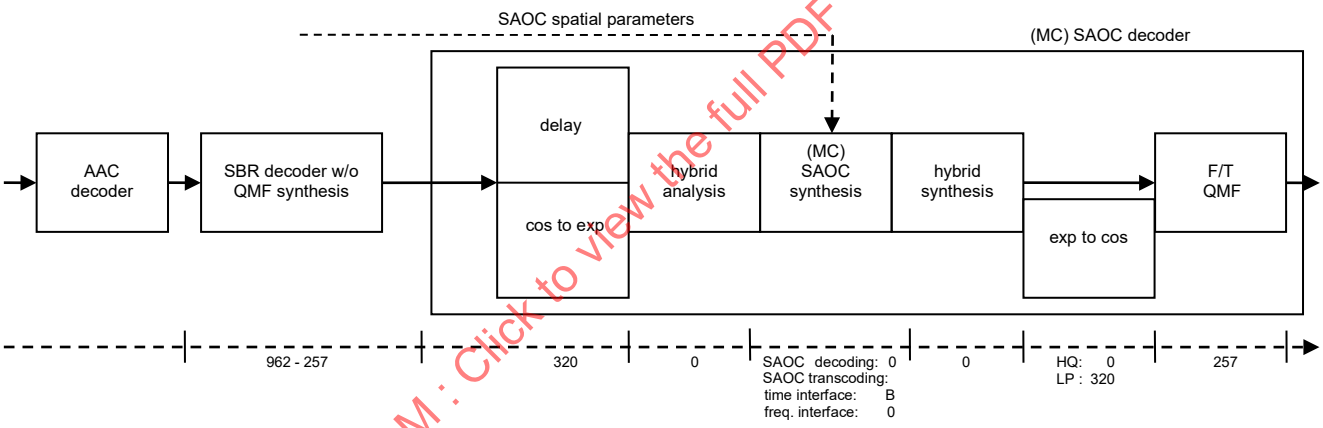

Figure 7 — Delay when connecting (MC-)SAOC with HE-AAC in the QMF domain

5.4.3 LD processing

5.4.3.1 SAOC Decoding

As outlined in 7.13 for the LD-SAOC processing, the Hybrid QMF filterbank is substituted by a LD QMF. In addition, no LP mode is allowed and hereafter no complex conversion is to be performed. As a result, the analysis and synthesis processing delays shall only depend on the LD QMF filtering, i.e. 160 time domain samples for analysis and 96 for synthesis. This is shown in Figure 8.

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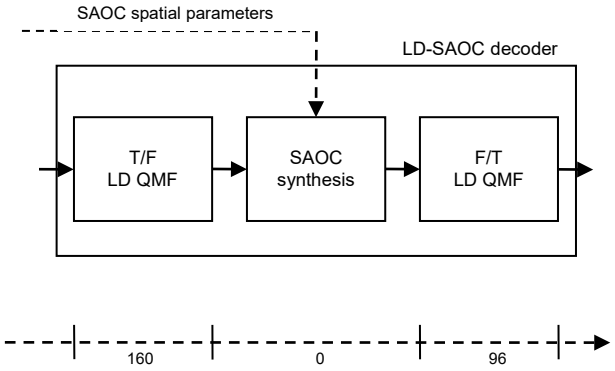

Figure 8 — Delay for the different parts of the LD-SAOC decoder

5.4.3.2 SAOC Transcoding

Equally to the non-LD MC-decoders, depending on the number of downmix channels (mono/stereo), the processing for the LD-MC-SAOC rendering scenarios is performed differently. Due to the delay constraints for a LD-SAOC system, no time domain interface is allowed for the stereo processing case. Hereafter, both mono and stereo downmix cases may be equally described with respect to the systems delay, matching the SAOC decoder delay distribution, as depicted in Figure 9 and Figure 10.

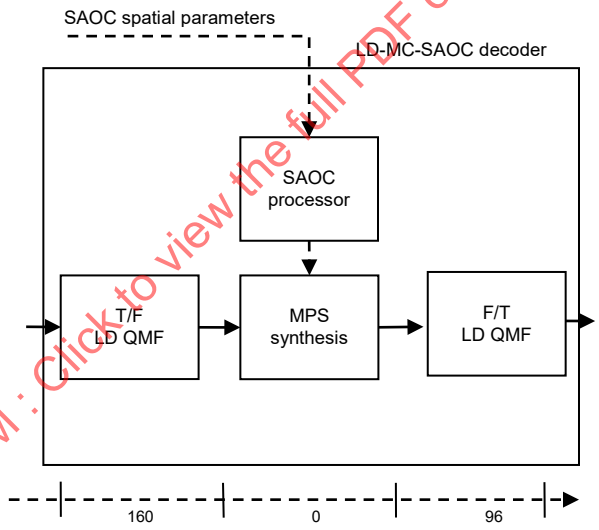

Figure 9 — Delay for the different parts of the LD-MC-SAOC decoder with mono downmix signal

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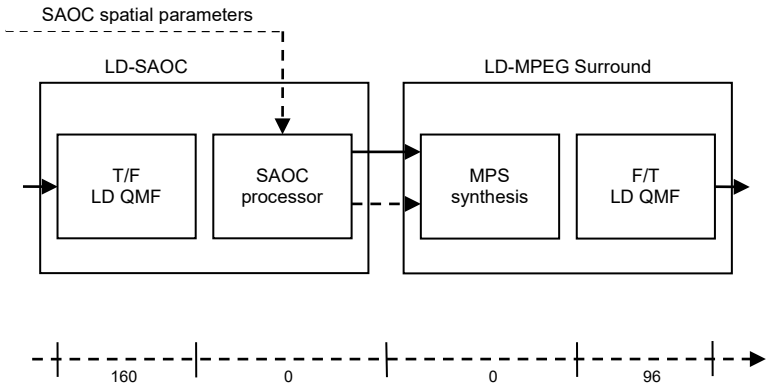

Figure 10 — Delay for the different parts of the LD-MC-SAOC decoder with stereo downmix signal

5.4.3.3 LD-(MC-)SAOC connection to LD core codec

If the LD-(MC-)SAOC decoder is connected with a LD downmix coder (e.g. AAC-LD or AAC-ELD, with/-out SBR) via the time domain, as shown in Figure 11, the additional delay introduced by the LD-(MC-)SAOC decoder processing is described above.

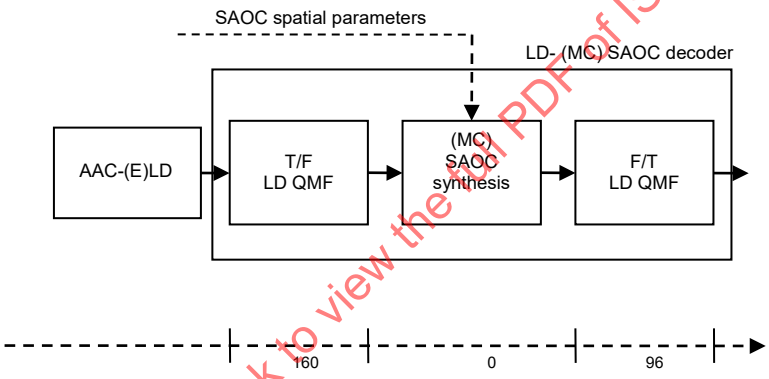

Figure 11 — Delay when connecting LD-(MC-)SAOC in the time-domain for a LD core codec (e.g. AAC-LD or AAC-ELD)

If the LD-(MC-)SAOC decoder is connected with a LD core coder via the frequency domain (e.g. AAC-ELD with SBR), as shown in Figure 12, the additional delay introduced by the LD-(MC-)SAOC decoder processing shall be reduced with respect to the description above, as no analysis is performed in the LD-(MC-)SAOC decoder.

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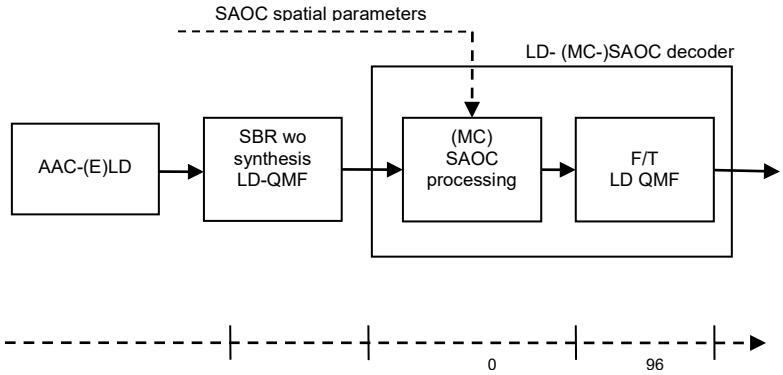

Figure 12 — Delay when connecting LD-(MC-) SAOC in the frequency-domain for a LD core codec (e.g. AAC-ELD with SBR)

5.5 SAOC Profiles and levels

5.5.1 General

This subclause defines profiles and their levels for SAOC.

Complexity units are defined to give an approximation of the decoder complexity in terms of processing power and RAM usage required for the SAOC decoding/transcoding process. The approximated processing power is given in "processor complexity units" (PCU), specified in MOPS. The approximated RAM usage is given in "ram complexity units" (RCU), specified in kWords (1 000 words).

Note that the following three profiles are independent from each other and are not intended to be interoperable on a bitstream or decoder level. Due to the underlying concept of SAOC, the number of output channels is independent of the bitstream. Depending on the decoder capabilities, the output channel configuration is selected via the user interface of the decoder.

5.5.2 Baseline profile

The baseline profile is the generic SAOC profile for all applications that are not delay critical. Within this profile, all SAOC decoders use the hybrid QMF filterbank and allow rendering to at least two output channels, based on the maximum number of supported downmix channels of two. Rendering to more than two output channels is optional.

An envisioned application scenario for the baseline profile includes, e.g. the following interactive re-mix application: a stereo (or mono) compressed signal or "track" can be provided to the consumer along with SAOC data describing the objects present in the track. With this, the user can create his or her own "re-"mix of the music or the sounds in the stereo (or mono) track, by playing back such object-based tracks with a control similar to that of a multi-track mixing desk and are therefore free to adjust relative level, spatial position, etc. of instruments, sounds or dialogue according to their preferences.

NOTE ISO/IEC 23000-12 defines several brands that refer to the SAOC baseline profile.

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5.5.3 LD profile

The SAOC-LD profile is targeted at applications that require low-delay operation. Within this profile, all SAOC decoders use the LD-QMF filterbank and allow rendering to at least two output channels. Rendering to more than two output channels is optional, with one exception: Level 3 requires the support for at least 5 output channels and includes a low-delay version of MPS as the rendering engine.

An envisioned application scenario for the LD profile includes, e.g. the following telecommunication application: existing monophonic infrastructures for telecommunication may be extended in their functionality easily by introducing SAOC with a single downmix channel. Telecommunication terminals equipped with an SAOC extension are able to pick up several sound sources (objects), mix them into a single (monophonic) downmix signal which is transmitted in a compatible way by using the existing coders (e.g. speech coders). The side information is conveyed in a hidden, backward compatible way. While such advanced terminals produce an output object stream containing several objects, legacy terminals will simply be considered as producing an object stream with a single embedded object.

5.5.4 Dialogue enhancement (SAOC-DE) profile

The dialogue enhancement profile is targeted at broadcast applications that desire dialogue enhancement functionality. Within this profile, all SAOC decoders use the hybrid QMF filterbank and allow rendering to mono, stereo or 3-channel output. The number of output channels is equal with the number of downmix channels.

An envisioned application scenario for the SAOC-DE profile includes, e.g. the following broadcasting application: by adding only a moderate bitrate overhead to a usual broadcast transport bitstream (the dialogue and background signals are already mixed together), the user will be provided with the option to enhance or attenuate the dialogue level in relation to all other signals contained in the mix. The side information is conveyed in a backwards-compatible way together with the encoded audio signal (e.g. using MPEG-4 AAC or HE-AAC) and therefore the legacy decoders will simply playback the default broadcast mixed signal.

The definition of the profiles and levels of SAOC is given in Table 4.

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Table 4 — SAOC profiles and levels

Profiles	Baseline profile				SAOC-DE profile		LD profile		
Levels	**1**	**2**	**3**	**4**	**1**	**2**	**1**	**2**	**3**
Hybrid QMF bank	X	X	X	X	X	X	—	—	—
LD-QMF bank	—	—	—	—	—	—	X	X	X
Max number of residual channels	0	2	4	4	0	3	—	—	—
Max sampling rate [kHz]	48	48	48	96	48	48	48	48	48
Max number of objects	8	16	32	32	6	6	8	32	32
Max number of downmix channels	2	2	2	2	3	3	1	2	2
Min number of required output channels[a]	2	2	2	2	1	1	2	2	5
Use of decorrelator	yes	yes	yes	yes	no	no	yes	yes	yes
PCU HQ decoder	12.2	20.4	33.9	67.8	12.4	22.1	8.4	20.7	39.3[b]
PCU LP decoder	6.6	12.2	23.0	46.0	11.4	21.0	N/A	N/A	N/A
PCU addition for transcoding	1.1	1.1	1.1	2.3	N/A	N/A	0.7	1.1	N/A
PCU reduction for integrated transcoding	−6.8	−6.8	−6.8	−6.8	N/A	N/A	−3.6	−6.5	N/A
RCU HQ decoder	5.7	9.8	13.5	17.5	6.3	12.3	3.6	4.2	17.9[c]
RCU LP decoder	4.8	5.4	5.7	10.3	7.3	7.9	N/A	N/A	N/A
RCU reduction for integrated transcoding	−1.3	−1.3	−1.3	−1.3	N/A	N/A	−0.6	−1.3	N/A

[a] Every SAOC decoder has to support rendering of SAOC content for every number of output channels up to the maximum number, as selected by the user interface. If the number of output channels >2, MPS is used to render the output signals in baseline and LD profiles. In SAOC-DE profile, the number of output channels shall be equal with the number of downmix channels.

[b] PCU number includes SAOC (20.7), transcoding overhead (1.1), reduction for integrated transcoding (-6.5) and an LD-MPS "5-2-5" decoder (24).

[c] RCU number includes SAOC (4.2), reduction for integrated transcoding (-1.3) and an LD-MPS "5-2-5" decoder (15).

The SAOC decoder type is defined by the four conditions:

— profile: baseline, LD or SAOC-DE profile;

— level: 1 to 4 (for baseline), 1 to 3 (for LD) or 1 to 2 (for SAOC-DE);

— HQ/LP: only applicable for baseline and SAOC-DE profiles;

— MPS transcoding support for baseline and LD profiles if the number of output channels >2.

For baseline and LD profiles:

— decoding to mono/stereo/binaural output. Transcoding to 5.1 is supported.

For dialogue enhancement (SAOC-DE) profile:

— decoding to mono/stereo/3-channel output. No transcoding to 5.1 is supported;

— multi-channel background object (MBO) processing, DCU processing, MCU processing, separation metadata and send effects interface are not supported;

— post-downmix gain processing (PDG) is supported only in combination with post(processing) re-application processing step;

— insert effects interface is supported only if no modification range control (MRC) settings are transported in the bitstream.

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6 Syntax

6.1 Payloads for SAOC

Table 5 — Syntax of SAOCSpecificConfig()

Syntax	No. of bits	Mnemonic
SAOCSpecificConfig()		
{		
bsSamplingFrequencyIndex;	**4**	**uimsbf**
if (bsSamplingFrequencyIndex == 15) {		
bsSamplingFrequency;	**24**	**uimsbf**
}		
bsLowDelayMode;	**1**	**uimsbf**
bsFreqRes;	**3**	**uimsbf**
if (bsLowDelayMode == 0) {		
bsFrameLength;	**7**	**uimsbf**
} else {		
bsFrameLength;	**5**	**uimsbf**
}		
bsNumObjects;	**5**	**uimsbf**
for (i=0; i<bsNumObjects+1; i++) {		
bsRelatedTo[i][i] = 1;		
for(j=i+1; j<bsNumObjects+1; j++) {		
bsRelatedTo[i][j];	**1**	**uimsbf**
bsRelatedTo[j][i] = bsRelatedTo[i][j];		
}		
}		
bsTransmitAbsNrg;	**1**	**uimsbf**
bsNumDmxChannels;	**1**	**uimsbf**
if (bsNumDmxChannels == 1) {		
bsTttDualMode;	**1**	**uimsbf**
if (bsTttDualMode) {		
bsTttBandsLow;	**5**	**uimsbf**
bsTttBandsHigh = numBands;		Note
} else {		
bsTttBandsLow = numBands;		
}		
}		
bsPdgFlag;	**1**	**uimsbf**
bsOneIOC;	**1**	**uimsbf**
bsDcuFlag;	**1**	**uimsbf**
if (bsDcuFlag == 1) {		
bsDcuMandatory;	**1**	**uimsbf**
bsDcuDynamic;	**1**	**uimsbf**
if (bsDcuDynamic == 0) {		
bsDcuMode;	**1**	**uimsbf**
bsDcuParam;	**4**	**uimsbf**
}		
} else {		
bsDcuMandatory = 0**;**		
bsDcuDynamic = 0**;**		
bsDcuMode = 0;		
bsDcuParam = 0;		
}		
ByteAlign();		
SAOCExtensionConfig();		
}		
NOTE numBands is defined in Table 36 and depends on bsFreqRes.		

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Table 6 — Syntax of SAOCDESpecificConfig()

Syntax	No. of bits	Mnemonic
SAOCDESpecificConfig()		
{		
bsVersion;	**4**	**uimsbf**
if (bsVersion == 0) {		
bsSamplingFrequencyIndex;	**4**	**uimsbf**
if (bsSamplingFrequencyIndex == 15) {		
bsSamplingFrequency;	**24**	**uimsbf**
}		
bsFreqRes;	**3**	**uimsbf**
bsFrameLength;	**7**	**uimsbf**
bsNumObjects;	**3**	**uimsbf**
bsNumFGOs;	**3**	**uimsbf**
for (i=0; i<bsNumObjects+1; i++) {		
bsRelatedTo[i][i] = 1;		
for(j=i+1; j<bsNumObjects+1; j++) {		
bsRelatedTo[i][j];	**1**	**uimsbf**
bsRelatedTo[j][i] = bsRelatedTo[i][j];		
}		
}		
bsNumDmxChannels;	**3**	**uimsbf**
bsPdgFlag;	**1**	**uimsbf**
bsOneIOC;	**1**	**uimsbf**
bsDeLimitFlag;	**1**	**uimsbf**
if (bsDeLimitFlag == 1) {		
bsDeLimitFgo;	**4**	**uimsbf**
bsDeLimitBgo;	**4**	**uimsbf**
} else {		
bsDeLimitFgo = 0;		
bsDeLimitBgo = 0;		
}		
bsDcuFlag;	**1**	**uimsbf**
if (bsDcuFlag == 1) {		
bsDcuMandatory;	**1**	**uimsbf**
bsDcuDynamic;	**1**	**uimsbf**
if (bsDcuDynamic == 0) {		
bsDcuMode;	**1**	**uimsbf**
bsDcuParam;	**4**	**uimsbf**
}		
} else {		
bsDcuMandatory = 0;		
bsDcuDynamic = 0;		
bsDcuMode = 0;		
bsDcuParam = 0;		
}		
ByteAlign();		
SAOCExtensionConfig();		
}		
}		
NOTE numBands is defined in Table 36 and depends on bsFreqRes.		

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Table 7 — Syntax of SAOCExtensionConfig()

Syntax	No. of bits	Mnemonic

SAOCExtensionConfig()
{
SaocExtNum = 0;
while (BitsAvailable() >= 8) {
bsSaocExtType;
SaocExtType[SaocExtNum] = bsSaocExtType;
SaocExtNum++;
cnt = **bsSaocExtLen**;
if (cnt==15) {
cnt += **bsSaocExtLenAdd**;
}
if (cnt==15+255) {
cnt += **bsSaocExtLenAddAdd**;
}
bitsRead = SAOCExtensionConfigData(bsSaocExtType)
nFillBits = 8*cnt-bitsRead;
bsFillBits;
}
}
	
	4
	
	4
	
	8
	
	16
	
	nFillBits
		
		Note 1
		uimsbf
		
		uimsbf
		
		uimsbf
		
		uimsbf
		
		Note 2
		
		bslbf

NOTE 1 The function BitsAvailable() returns the number of bits available to be read. NOTE 2 SAOCExtensionConfigData() returns the number of bits read.		

Table 8 — Syntax of SAOCExtensionConfigData(0)

Syntax	No. of bits	Mnemonic

SAOCExtensionConfigData(0)
{
if (bsDeLimitFlag == 1) {
bsDeLimitFgoEAO;
bsDeLimitBgoEAO;
} else {
bsDeLimitFgoEAO = 0;
bsDeLimitBgoEAO = 0;
}
if (bsDcuFlag == 1) {
bsDcuFlag2;
if ((bsDcuFlag2 == 1) && (bsDcuDynamic == 0)) {
bsDcuMode2;
bsDcuParam2;
}
}
ResidualConfig();
}
	
	4
	4
	
	1
	
	1
	4
		
		uimsbf
		uimsbf
		
		uimsbf
		
		uimsbf
		uimsbf

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Table 9 — Syntax of ResidualConfig()

Syntax	No. of bits	Mnemonic

ResidualConfig()
{
  bsResidualSamplingFrequencyIndex;
  bsResidualFramesPerSAOCFrame;
  bsNumEAO;
  for (i=0; i<bsNumEAO + 1; i++) {
  bsResidualPresent[i];
  if (bsResidualPresent[i]) {
  bsResidualBands[i];
  }
  bsTtnDualMode[i];
  if (bsTtnDualMode[i]) {
  bsTtnBandsLow[i];
  } else {
  bsTtnBandsLow[i] = numBands;
  }
  }
}
	
	4
	2
	2
	
	1
	
	5
	
	1
	
	5
	
		uimsbf
		uimsbf
		uimsbf
		
		uimsbf
		
		uimsbf
		
		uimsbf
		
		uimsbf
		
		Note

NOTE numBands is defined in Table 36 and depends on bsFreqRes.		

Table 10 — Syntax of SAOCExtensionConfigData(1)

Syntax	No. of bits	Mnemonic

SAOCExtensionConfigData(1)
{
}		

Table 11 — Syntax of SAOCExtensionConfigData(2)

Syntax	No. of bits	Mnemonic

SAOCExtensionConfigData(2)
{
  SpatialSpecificConfig();
}
		
		Note

NOTE SpatialSpecificConfig() is defined in ISO/IEC 23003-1:2007, Table 5.		

Table 12 — Syntax of SAOCExtensionConfigData(3)

Syntax	No. of bits	Mnemonic

SAOCExtensionConfigData(3)
{
}		

Table 13 — Syntax of SAOCExtensionConfigData(8)

Syntax	No. of bits	Mnemonic

SAOCExtensionConfigData(8)
{
  ObjectMetaData();
}		

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Table 14 —Syntax of ObjectMetaData()

Syntax	No. of bits	Mnemonic

ObjectMetaData()
{
  for (i=0; i<bsNumObjects+1; i++) {
  bsNumByteMetaData[i];
	8	**uimsbf**

for (j=0; j<bsNumByteMetaData[i]; j++) { **bsMetaData**[i][j];	**8**	**bslbf**
} } }		

Table 15 — Syntax of SAOCExtensionConfigData(9)

Syntax	No. of bits	Mnemonic

SAOCExtensionConfigData(9)
{
  PresetConfig();
}		

Table 16 — Syntax of PresetConfig()

Syntax	No. of bits	Mnemonic
PresetConfig() { **bsNumPresets**;	**4**	**uimsbf**
for (i=0; i<bsNumPresets+1; i++) { **bsNumBytePresetLabel**[i];	**8**	**uimsbf**
for (j=0; j<bsNumBytePresetLabel[i]; j++) { **bsPresetLabel**[i][j];	**8**	**bslbf**
} **bsPresetMatrix**[i]**;**	**1**	**uimsbf**

if (bsPresetMatrix[i]) {
  PresetMatrixData();
  } else {
  PresetUserData();
  }
  }
}		

Table 17 — Syntax of PresetMatrixData()

Syntax	No. of bits	Mnemonic
PresetMatrixData() { **bsPresetMatrixType**;	**2**	**uimsbf**

for(i=0; i<bsNumObjects+1; i++) {
  numChannels = PresetMatrixType[bsPresetMatrixType];
  for(j=0; j<numChannels; i++) {
  bsPresetMatrixElements[i][j];
	5	**uimsbf**

} } }		

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Table 18 — Syntax of PresetUserData()

Syntax	No. of bits	Mnemonic
PresetUserData()		
{		
for(i=0; i<6; i++) {		
bsPresetUserDataIdentifier[i];	**8**	**bslbf**
}		
bsPresetUserDataLen;	**12**	**uimsbf**
PresetUserDataContainer(bsPresetUserDataIdentifier);		
}		

Table 19 — Syntax of SAOCExtensionConfigData(10)

Syntax	No. of bits	Mnemonic
SAOCExtensionConfigData(10)		
{		
SeparationMetaData();		
}		

Table 20 — Syntax of SeparationMetaData()

Syntax	No. of bits	Mnemonic
SeparationMetaData()		
{		
bsNumSeparationPairs;	**4**	**uimsbf**
for (i=0; i<bsNumSeparationPairs+1; i++) {		
bsSeparationMainObjectID[i];	**5**	**uimsbf**
bsSeparationSubObjectID[i];	**5**	**uimsbf**
}		
}		

Table 21 — Syntax of SAOCFrame()

Syntax	No. of bits	Mnemonic
SAOCFrame()		
{		
SAOCFramingInfo();		
bsIndependencyFlag;	**1**	**uimsbf**
for(i=0; i<bsNumObjects+1; i++) {		
idxOLD[i] = EcDataSaoc(OLD, i, numBands);		
}		
if (bsTransmitAbsNrg) {		
idxNRG = EcDataSaoc(NRG, 0, numBands);		
}		
k=0;		
iocIdx1=0;		
iocIdx2=0;		
for(i=0; i<bsNumObjects+1; i++) {		
idxIOC[i][i] = 0;		
for(j=i+1; j<bsNumObjects+1; j++) {		
if (bsRelatedTo[i][j] != 0) {		
if (bsOneIOC == 0) {		
idxIOC[i][j] = EcDataSaoc(IOC, k, numBands);		
k++;		

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```
                    } else {
                        if ( k == 0 ) {
                            idxIOC[i][j] = EcDataSaoc(IOC, k, numBands);
                            k++;
                            iocIdx1=i;
                            iocIdx2=j;
                        } else {
                            idxIOC[i][j] = idxIOC[iocIdx1][iocIdx2];
                        }
                    }
                } else {
                    idxIOC[i][j] = 5;
                }
                idxIOC[j][i] = idxIOC[i][j];
            }
        }
        idxDMG = EcDataSaoc(DMG, 0, bsNumObjects+1);
        if ( bsNumDmxChannels == 1 ) {
            idxDCLD = EcDataSaoc(DCLD, 0, bsNumObjects+1);
        }
        if ( bsPdgFlag == 1 ) {
            for (i=0; i<bsNumDmxChannels + 1; i++) {
                idxPDG[i] = EcDataSaoc(DCLD, i, numBands);                    Note
            }
        }
        if ( bsDcuFlag == 1 ) && ( bsDcuDynamic == 1 ) {
            if ( bsIndependencyFlag == 1 ) {
                bsDcuDynamicUpdate = 1;
            } else {
                bsDcuDynamicUpdate;                                  1        uimsbf
            }
            if ( bsDcuDynamicUpdate == 1 ) {
                bsDcuMode;                                           1        uimsbf
                bsDcuParam;                                          4        uimsbf
            }
        }
        ByteAlign();
        SAOCExtensionFrame();
}
```

NOTE numBands is defined in Table 36 and depends on bsFreqRes.

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Table 22 — Syntax of SAOCDEFrame()

Syntax	No. of bits	Mnemonic

SAOCDEFrame()
{
SAOCDEFramingInfo();
if (bsVersion == 0) {
bsIndependencyFlag;
	1	**uimsbf**

for(i=0; i<bsNumObjects+1; i++) {
idxOLD[i] = EcDataSaoc(OLD, i, numBands);
}
k=0;
iocIdx1=0;
iocIdx2=0;
for(i=0; i<bsNumObjects+1; i++) {
idxIOC[i][i] = 0;
for(j=i+1; j<bsNumObjects+1; j++) {
if (bsRelatedTo[i][j] != 0) {
if (bsOneIOC == 0) {
idxIOC[i][j] = EcDataSaoc(IOC, k, numBands);
k++;
} else {
if (k == 0)
idxIOC[i][j] = EcDataSaoc(IOC, k, numBands);
k++;
iocIdx1=i;
iocIdx2=j;
} else {
idxIOC[i][j] = idxIOC[iocIdx1][iocIdx2];
}
}
} else {
idxIOC[i][j] = 5;
}
idxIOC[j][i] = idxIOC[i][j];
}
}
for (i=0; i<bsNumDmxChannels + 1; i++) {
idxDMG[i] = EcDataSaoc(DMG, i, bsNumObjects+1);
}
if (bsPdgFlag == 1) {
for (i=0; i<bsNumDmxChannels + 1; i++) {
idxPDG[i] = EcDataSaoc(DCLD, i, numBands);
		Note

}
if (bsDeLimitFlag == 1) {
if (bsIndependencyFlag == 1) {
bsDeLimitUpdate = 1;
} else {
bsDeLimitUpdate;
}
if (bsDeLimitUpdate == 1) {
bsDeLimitFgo;
bsDeLimitBgo;
}
}
if (bsDcuFlag == 1) && (bsDcuDynamic == 1) {
if (bsIndependencyFlag == 1) {
bsDcuDynamicUpdate = 1;
	1
	4
	4
		uimsbf
		uimsbf
		uimsbf

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} else {		
bsDcuDynamicUpdate;	**1**	**uimsbf**
}		
if (bsDcuDynamicUpdate == 1) {		
bsDcuMode;	**1**	**uimsbf**
bsDcuParam;	**4**	**uimsbf**
}		
}		
ByteAlign();		
SAOCExtensionFrame();		
}		
}		
NOTE numBands is defined in Table 36 and depends on bsFreqRes.		

Table 23 — Syntax of SAOCFramingInfo()

Syntax	No. of bits	Mnemonic
SAOCFramingInfo()		
{		
bsFramingType;	**1**	**uimsbf**
If (bsLowDelayMode == 0) {		
bsNumParamSets;	**3**	**uimsbf**
} else {		
bsNumParamSets;	**1**	**uimsbf**
}		
for (ps=0; ps<numParamSets; ps++) {		
if (bsFramingType) {		Note 1
bsParamSlot[ps];	**nBitsParamSlot**	**uimsbf** Note 2
} else {		
bsParamSlot[ps] =ceil(numSlots*(ps+1)/numParamSets)-1;		Notes 1 and 3
}		
}		
}		
NOTE 1 numParamSets is defined by numParamSets = bsNumParamSets + 1.		
NOTE 2 nBitsParamSlot is defined according to nBitsParamSlot = ceil[log2(numSlots)].		
NOTE 3 numSlots is defined by numSlots = bsFrameLength + 1.		

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Table 24 — EcDataSaoc()

Syntax	No. of bits	Mnemonic
EcDataSaoc(dataType, paramIdx, stopIdx)		Note 1
{		
dataSets = 0;		
for (ps=0; ps<bsNumParamSets + 1; ps++) {		
bsXXXdataMode[paramIdx][ps];	**2**	**uimsbf**
if (bsXXXdataMode[paramIdx][ps] == 3) {		
dataSets++;		
}		
}		
setIdx = 0;		
while (setIdx < dataSets) {		
If (dataSets-setIdx > 1) {		
bsDataPairXXX[paramIdx][setIdx];	**1**	**uimsbf**
} else {		
bsDataPairXXX[paramIdx][setIdx] = 0;		
}		
bsQuantCoarseXXX[paramIdx][setIdx];	**1**	**uimsbf**
bsFreqResStrideXXX[paramIdx][setIdx];	**2**	**uimsbf**
dataDim = (stopIdx-1)/pbStride+1;		Note 2
SAOCEcDataPair(dataType, paramIdx, setIdx, dataDim, bsDataPairXXX[paramIdx][setIdx], bsQuantCoarseXXX[paramIdx][setIdx]);		
if (bsDataPairXXX[paramIdx][setIdx]) {		
bsXXXQuantCoarse[paramIdx][setIdx+1] = bsXXXQuantCoarse[paramIdx][setIdx];		
bsFreqResStrideXXX[paramIdx][setIdx+1] = bsFreqResStrideXXX[paramIdx][setIdx];		
}		
setIdx += bsDataPairXXX[paramIdx][setIdx]+1;		
}		
stopIdxXXX[paramIdx] = stopIdx;		
}		
NOTE 1 XXX is to be replaced by the value of dataType (OLD, IOC, NRG, DCLD, DMG).		
NOTE 2 pbStride is defined in ISO/IEC 23003-1:2007, Table 70 and depends on bsFreqResStride[][]. Furthermore, the division shall be interpreted as ANSI C integer division.		

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Table 25 — Syntax of SAOCEcDataPair()

Syntax	No. of bits	Mnemonic
SAOCEcDataPair(dataType, paramIdx, setIdx, dataBands, pairFlag, coarseFlag)		Note 1
{		
mixedTimePair_flag = 0;		
bsPcmCodingXXX[paramIdx][setIdx];	**1**	**uimsbf**
if (bsPcmCoding[paramIdx][setIdx]) {		
if (coarseFlag) {		
numQuantSteps = numQuantStepsXXXCoarse;		Note 2
} else {		
numQuantSteps = numQuantStepsXXXFine;		Note 2
}		
aaDataPair = GroupedPcmData(dataType, pairFlag, numQuantSteps, dataBands);		Note 3
} else {		
allowDiffTimeBack = (!bsIndependencyFlag) || (setIdx>0);		
(aaDataPairMsbDiff, aPgOffset, mixedTimePair_flag) = SAOCDiffHuffData(dataType, pairFlag, allowDiffTimeBack, dataBands);		
aaDataPairLsb[0] = LsbData(dataType, coarseFlag, dataBands);		Note 4
if (pairFlag) {		
aaDataPairLsb[1] = LsbData(dataType, coarseFlag, dataBands);		Note 4
}		
}		
bsDiffTypeXXX[paramIdx][setIdx] = bsDiffType[0];		
bsDiffTimeDirectionXXX[paramIdx][setIdx] = bsDiffTimeDirection[0];		
mixedTimePairXXX[paramIdx][setIdx] = mixedTimePair_flag;		
if (pairFlag) {		
bsDiffTypeXXX[paramIdx][setIdx+1] = bsDiffType[1];		
bsDiffTimeDirectionXXX[paramIdx][setIdx+1] = bsDiffTimeDirection[1];		
bsPcmCodingXXX[paramIdx][setIdx+1] = bsPcmCodingXXX[paramIdx][setIdx];		
mixedTimePairXXX[paramIdx][setIdx+1] = mixedTimePair_flag;		
}		
for (pg=0; pg<dataBands; pg++) {		
if (bsPcmCodingXXX[paramIdx][setIdx]) {		
bsXXXpcm[paramIdx][setIdx][pg] = aaDataPair[0][pg];		
} else {		
bsXXXmsbDiff[paramIdx][setIdx][pg] = aaDataPairMsbDiff[0][pg];		
bsXXXlsb[paramIdx][setIdx][pg] = aaDataPairLsb[0][pg];		
}		
if (pairFlag) {		
if (bsPcmCodingXXX[paramIdx][setIdx+1]) {		
bsXXXpcm[paramIdx][setIdx+1][pg] = aaDataPair[1][pg];		
} else {		
bsXXXmsbDiff[paramIdx][setIdx+1][pg] =aaDataPairMsbDiff[1][pg];		
bsXXXlsb[paramIdx][setIdx+1][pg] = aaDataPairLsb[1][pg];		
}		
}		
}		
}		

NOTE 1 XXX is to be replaced by the value of dataType (OLD, IOC, NRG, DCLD, DMG, PDG).
NOTE 2 numQuantStepsXXXCoarse and numQuantStepsXXXFine is defined in Table 48 and depends on dataType.
NOTE 3 GroupedPcmData() is defined in ISO/IEC 23003-1:2007, Table 25.
NOTE 4 LsbData() is defined in ISO/IEC 23003-1:2007, Table 31.

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Table 26 — Syntax of SAOCDiffHuffData()

Syntax	No. of bits	Mnemonic
SAOCDiffHuffData(dataType, pairFlag, allowDiffTimeBackFlag, dataBands)		
{		
mixedTimePair_flag = 0;		
bsDiffType[0] = DIFF_FREQ;		
bsDiffType[1] = DIFF_FREQ;		
if (pairFlag || allowDiffTimeBackFlag) {		
bsDiffType[0];	**1**	**uimsbf**
}		
if (pairFlag && ((bsDiffType[0] == DIFF_FREQ) || allowDiffTimeBackFlag)) {		
bsDiffType[1];	**1**	**uimsbf**
}		
bsCodingScheme;	**1**	**uimsbf**
if (bsCodingScheme == HUFF_1D) {		
(aaHuffData[0]) = SAOCHuffData1D(dataType, aDiffType[0],dataBands);		
if (pairFlag) {		
(aaHuffData[1]) =		
SAOCHuffData1D(dataType, aDiffType[1],dataBands);		
}		
} else {		
bsPairing = FREQ_PAIR;		
(aaHuffData[0]) =		
SAOCHuffData2DFreqPair(dataType, aDiffType[0], dataBands);		
If (pairFlag) {		
(aaHuffData[1]) =		
SAOCHuffData2DFreqPair(dataType, aDiffType[1], dataBands);		
}		
}		
if ((bsDiffType[0] == DIFF_TIME) || (bsDiffType[1] == DIFF_TIME)) {		
bsDiffTimeDirection[0] = BACKWARDS;		
if (pairFlag) {		
bsDiffTimeDirection[1] = BACKWARDS;		
}		
}		
return (aaHuffData, aPgOffset, mixedTimePair_flag);		
}		

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Table 27 — Syntax of SAOCHuffData1D()

Syntax	No. of bits	Mnemonic

SAOCHuffData1D(dataType, diffType, dataBands)
{
pgOffset = 0;
if (diffType == DIFF_FREQ) {
aHuffData1D[0] = 1Dhuff_dec(hcodFirstBand_XXX, **bsCodeW**);
	1..x	**vlclbf**
		Notes 1 and 3

pgOffset = 1;
}
for (i=pgOffset; i<dataBands; i++) {
aHuffData1D[i] = 1Dhuff_dec(hcod1D_XXX_YY, **bsCodeW**);
	1..x	**vlclbf**
		Notes 1, 2 and 3

if (aHuffData1D[i] != 0) { **bsSign**;	**1**	**uimsbf**

if (bsSign) {
aHuffData1D[i] = -aHuffData1D[i];
}
}
}
return (aHuffData1D);
}		

NOTE 1 XXX is to be replaced by the value of dataType (OLD, IOC, NRG, DCLD, DMG, PDG). NOTE 2 YY is to be replaced by "DF" or "DT", depending on the value of diffType. NOTE 3 1Dhuff_dec() is defined in ISO/IEC 23003-1:2007, Annex A.1.		

Table 28 — Syntax of SAOCHuffData2DFreqPair()

Syntax	No. of bits	Mnemonic
SAOCHuffData2DFreqPair(dataType, diffType, dataBands) { LavIdx = 1Dhuff_dec(hcodLavIdx, **bsCodeW**);	**1..3**	**vlclbf**

lav = lavTabXXX[LavIdx];
 	
pgOffset = 0;
 	
if (diffType == DIFF_FREQ) {
		NOTE 1

aHuffData2D[0] = 1Dhuff_dec(hcodFirstBand_XXX, **bsCodeW**);	**1..x**	**vlclbf** Note 6

pgOffset = 1;
}
escapeCode = hcod2D_XXX_YY_FP_LL_escape;
 	
escCntr = 0;
for (i=pgOffset; i<dataBands; i+=2) {
		Notes 2, 3, 4 and 5

(aTmp[0], aTmp[1]) = 2Dhuff_dec(hcod2D_XXX_YY_FP_LL, **bsCodeW**);	**1..x**	**vlclbf** Notes 3, 4, 5 and 6

if (bsCodeWord != escapeCode) {
aTmpSym = SymmetryData(aTmp);
aHuffData2D[i] = aTmpSym[0];
aHuffData2D[i+1] = aTmpSym[1];
} else {
aEscList[escCntr++] = i;
}		

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}
if (escCntr > 0) {
aaEscData = GroupedPcmData(dataType, 1, 2*lav+1, escCntr);
for (i=0; i<escCntr; i++) {
aHuffData2D[aEscList[i]] = aaEscData[0][i] - lav;
aHuffData2D[aEscList[i]+1] = aaEscData[1][i] - lav;
}
}
if ((dataBands-pgOffset) % 2) {
		Note 7

aHuffData2D[dataBands-1] = 1Dhuff_dec(hcod1D_XXX_YY, **bsCodeW**);	**1..x**	**vlclbf** Notes 3, 4 and 6
if (aHuffData2D[dataBands-1] != 0) { **bsSign**;	**1**	**uimsbf**

if (bsSign) {
aHuffData2D[dataBands-1] = -aHuffData2D[dataBands-1];
}
}
}
return (aHuffData2D);
}		

NOTE 1 lavTabXXX is defined in Table 46 and Table 47.
NOTE 2 The escape code tables are defined in Table A.6, Table A.7 and Table A.8.
NOTE 3 XXX is to be replaced by the value of dataType (OLD, IOC, NRG, DCLD, DMG, PDG).
NOTE 4 YY is to be replaced by "DF" or "DT", depending on the value of diffType.
NOTE 5 LL is to be replaced by the value of lav.
NOTE 6 1Dhuff_dec() and 2Dhuff_dec() are defined in ISO/IEC 23003-1:2007, Annex A.1.
NOTE 7 % denotes the modulo operator (ANSI C integer math) and returns the remainder of the division.

Table 29 — Syntax of SAOCExtensionFrame()

Syntax	No. of bits	Mnemonic

SAOCExtensionFrame()
{
for (ec=0; ec<SaocExtNum; ec++){
if (SaocExtType[ec]<8) {
cnt = **bsSaocExtLen**;
	8	**uimsbf**

if (cnt==255) { cnt += **bsSaocExtLenAdd**;	**16**	**uimsbf**

}
if (cnt>0) {
bitsRead = SAOCExtensionFrameData(SaocExtType[ec])
		Note 1

}
nFillBits = 8*cnt-bitsRead;
bsFillBits;
	nFillBits	**bslbf**

} } }		

NOTE 1 SAOCExtensionFrameData() returns the number of bits read.

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Table 30 — Syntax of SAOCExtensionFrameData(0)

Syntax	No. of bits	Mnemonic

SAOCExtensionFrameData(0)
{
  if (bsDeLimitFlag == 1) {
  if (bsIndependencyFlag == 1) {
  bsDeLimitEaoUpdate = 1;
  } else {
  bsDeLimitEaoUpdate;
	1	**uimsbf**

}
  if (bsDeLimitEaoUpdate == 1) {
  bsDeLimitFgoEAO;
  bsDeLimitBgoEAO;
	4
	4
		uimsbf
		uimsbf

}
  }
  if ((bsDcuFlag == 1) && (bsDcuFlag2 == 1) && (bsDcuDynamic == 1)) {
  if (bsIndependencyFlag == 1) {
  bsDcuDynamicUpdate2 = 1**;**
  } else {
  bsDcuDynamicUpdate2;
	1	**uimsbf**

}
  if (bsDcuDynamicUpdate2 == 1) {
  bsDcuMode2;
  bsDcuParam2;
	1
	4
		uimsbf
		uimsbf

}
  }
  SAOCResidualData();
}		

Table 31 — Syntax of SAOCResidualData()

Syntax	No. of bits	Mnemonic

SAOCResidualData()
{
  for (i=0; i<bsNumEAO + 1; i++) {
  if (bsResidualPresent[i]) {
  individual_channel_stream(0);
		Note 1

} } }		
NOTE 1 individual_channel_stream(0) according to MPEG-2 AAC Low Complexity profile bitstream syntax described in ISO/IEC 13818-7:2006, 6.3.		

Table 32 — Syntax of SAOCExtensionFrameData(1)

Syntax	No. of bits	Mnemonic

SAOCExtensionFrameData(1)
{
  PresetConfig();
}		

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Table 33 — Syntax of SAOCExtensionFrameData(2)

Syntax	No. of bits	Mnemonic

SAOCExtensionFrameData(2)
{
SpatialFrame();
}
		Note 1

NOTE 1 SpatialFrame() is defined in ISO/IEC 23003-1:2007, Table 15.		

Table 34 — Syntax of SAOCExtensionFrameData(3)

Syntax	No. of bits	Mnemonic

SAOCExtensionFrameData(3)
{
ObjectMetaData();
}		

6.2 Definition

ByteAlign() Up to 7 fill bits to achieve byte alignment with respect to the beginning of the syntactic element in which ByteAlign() occurs.

SAOCSpecificConfig() Syntactic element that contains the SAOC configuration data (header).

SAOCDESpecificConfig()

Syntactic element that contains the SAOC configuration data (header) in case of SAOC-DE profile.

bsVersion Defines the version of the bitstream according to Table 35.

Table 35 — bsVersion

bsVersion	**Meaning**
0	SAOC-DE profile, levels 1 and 2
1 .. 15	Reserved

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bsSamplingFrequencyIndex
See ISO/IEC 14496-3:2009, 1.6.3.4.

bsSamplingFrequency See ISO/IEC 14496-3:2009, 1.6.3.3.

bsFreqRes Defines the number of parameter bands according to Table 36.

Table 36 — bsFreqRes

bsFreqRes	numBands	
	bsLowDelayMode==0	**bsLowDelayMode**==1
0	N/A	N/A
1	28	23
2	20	15
3	14	12
4	10	9
5	7	7
6	5	5
7	4	4

bsLowDelayMode Indicates whether the SAOC operates in HQ or LD mode according to Table 37.

Table 37 — bsLowDelayMode

bsLowDelayMode	Meaning
0	HQ operation mode
1	LD operation mode (see 7.14)

In case of SAOC-DE profile, **bsLowDelayMode** shall be set to 0.

bsTttBandsHigh Same as bsTttBandsLow but for high band range. The high band range is **bsTttBandsLow** <= pb < **bsTttBandsHigh**.

bsFrameLength Defines the number of time slots in an SAOC frame.

bsNumObjects Defines the number of object channels for which SAOC parameters are transmitted.

In case of stereo or multi-channel objects, each channel counts as separate object.

bsNumFGOs Defines the number of FGOs according to Table 38.

Table 38 — bsNumFGOs

bsNumFGOs	Meaning
0	$N_{FGO} = 1$
1	$N_{FGO} = 2$
2	$N_{FGO} = 3$
3,...,7	N/A

bsRelatedTo[i][j] Defines whether an object has relation with other objects. More precisely, **bsRelatedTo**[i][j] == 1 means that object *i* and object *j* are related, i.e. have correlation, whereas **bsRelatedTo**[i][j] == 0 means that this is not the case.

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bsTransmitAbsNrg Defines whether absolute energy parameters are transmitted. These are necessary for delay-free merging of SAOC bitstreams in an MCU bitstream combiner.

bsNumDmxChannels Defines the number of downmix channels according to Table 39.

Table 39 — bsNumDmxChannels

bsNumDmxChannels	Meaning
0	mono downmix
1	stereo downmix
2	3-channel downmix
3,...,7	N/A

bsTttDualMode Indicates if transcoding to the TTT box operates in different modes for a low and high band range according to Table 40.

Table 40 — bsTttDualMode

bsTttDualMode	Meaning
0	same TTT transcoding mode for full band range (i.e. no separate high band range)
1	different TTT transcoding modes for low and high band ranges

bsTttBandsLow Defines the number of parameter bands for which TTT transcoding should be processed according to prediction or energy based scheme.
Prediction based scheme should be used for the parameter band range:
0 <= pb < **bsTttBandsLow**.
Energy based scheme should be used for the parameter band range:
bsTttBandsLow <= pb < **numBands**.

bsTtnDualMode Indicates if transcoding to the OTN/TTN box operates in different modes for a low and high band range according to Table 41.

Table 41 — bsTtnDualMode[i]

bsTtnDualMode[i]	Meaning
0	same OTN/TTN transcoding mode for full band range (i.e. no separate high band range)
1	different OTN/TTN transcoding modes for low and high band ranges

bsTtnBandsLow Defines the number of parameter bands for which OTN/TTN transcoding should be processed according to prediction or energy based scheme. Prediction based scheme should be used for the parameter band range: 0 <= pb < **bsTtnBandsLow**. Energy based scheme should be used for the parameter band range: **bsTtnBandsLow** <= pb < numBands.

bsPdgFlag Defines whether PDG parameters are transmitted according to Table 42.

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Table 42 — bsPdgFlag

bsPdgFlag	Meaning
0	PDG parameters are not transmitted
1	PDG parameters are transmitted

bsDcuFlag Defines whether the values **bsDcuMode** and **bsDcuParam** are transmitted in the bitstream.

bsDcuFlag2 Defines whether the values **bsDcuMode2** and **bsDcuParam2** are transmitted in the bitstream.

bsDcuMandatory If **bsDcuMandatory** == 1, then the DCU shall be applied using the parameters **bsDcuMode** and **bsDcuParam** as transmitted in the bitstream. If **bsDcuMandatory** == 0, then the DCU parameters **bsDcuMode** and **bsDcuParam** transmitted in the bitstream are only recommended values and also other DCU settings could be used.

bsDcuDynamic Enables dynamic signaling of the values **bsDcuMode** and **bsDcuParam**.

bsDcuDynamicUpdate Defines whether the values **bsDcuMode** and **bsDcuParam** are updated. More precisely, **bsDcuDynamicUpdate** == 1 means that the values **bsDcuMode** and **bsDcuParam** are updated in the current frame, whereas **bsDcuDynamicUpdate** == 0 means that the previously transmitted values are kept.

bsDcuDynamicUpdate2
Same as **bsDcuDynamicUpdate** but for application only in strict EAO mode.

bsDcuMode Defines the distortion-free target matrix type for the DCU according to Table 43.

Table 43 — bsDcuMode

bsDcuMode	Meaning
0	Downmix-similar target matrix
1	Best-effort target matrix

bsDcuMode2 Same as **bsDcuMode** but for application only in strict EAO mode.

bsDcuParam Defines the parameter value for the DCU algorithm according to Table 44.

Table 44 — bsDcuParam parameters quantization table

idx	0	1	2	3	4	5	6	7
DcuParam[idx]	0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35
idx	8	9	10	11	12	13	14	15
DcuParam[idx]	0.40	0.45	0.50	0.60	0.70	0.80	0.90	1.00

bsDcuParam2 Same as **bsDcuParam**, but for application only in strict EAO mode.

bsOneIOC Indicates if only a single IOC parameter is conveyed common to all objects which have relation with other, signalled by **bsRelatedTo**[i][j] == 1.

bsDeLimitFlag Defines whether the values **bsDeLimitFgo**, **bsDeLimitFgoEAO**, **bsDeLimitBgo,** and **bsDeLimitBgoEAO** are transmitted in the bitstream. In case of baseline or LD profiles, **bsDeLimitFlag** shall be set to 0.

bsDeLimitFgo Defines the value representing the lowest acceptable modification boundary related to the FGO for the modification range control algorithm according to Table 45.

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Table 45 — bsDeLimitFgo, bsDeLimitFgoEAO, bsDeLimitBgo and bsDeLimitBgoEAO parameters quantization table

idx	0	1	2	3	4	5	6	7
DeLimit[idx]	$10^{-7.50}$	$10^{-2.25}$	$10^{-2.00}$	$10^{-1.75}$	$10^{-1.50}$	$10^{-1.25}$	$10^{-1.10}$	$10^{-0.95}$
idx	8	9	10	11	12	13	14	15
DeLimit[idx]	$10^{-0.80}$	$10^{-0.65}$	$10^{-0.50}$	$10^{-0.40}$	$10^{-0.30}$	$10^{-0.20}$	$10^{-0.10}$	1

bsDeLimitBgo Defines the value representing the lowest acceptable modification boundary related to the BGO for the modification range control algorithm according to Table 45.

bsDeLimitFgoEAO Same as **bsDeLimitFgo** but for application only in strict EAO mode.

bsDeLimitBgoEAO Same as **bsDeLimitBgo** but for application only in strict EAO mode.

bsObjectMetaDataAvailable

Defines whether or not metadata information for the encoded objects is transmitted.

ObjectMetaData() Syntactic element that contains a metadata description of the the encoded objects.

bsNumEAO Defines the number of EAO channels.

bsResidualFramesPerSAOCFrame

Indicates the number of residual frames per SAOC frame, ranging from one to four according to ISO/IEC 23003-1:2007, Table 56.

bsNumByteMetaData[i]

Defines the number of bytes used for the metadata description of an object, *i*.

bsMetaData[i][j] Defines the metadata description (interpreted as a string in UTF-8 encoding format).

SAOCFrame() Syntactic element that contains the data of an SAOC frame (payload).

SAOCDEFrame() Syntactic element that contains the data of an SAOC frame (payload) in case of SAOC-DE profile.

SAOCFramingInfo() Syntactic element that contains information about the number of parameter sets and their associated time slots.

bsIndependencyFlag Indicates if lossless coding of the current SAOC frame is done independently of the previous SAOC frame, i.e. whether the current SAOC frame can be decoded without knowledge about the previous SAOC frame.

bsDeLimitUpdate Defines whether the values **bsDeLimitFgo**, **bsDeLimitFgoEAO**, **bsDeLimitBgo** and **bsDeLimitBgoEAO** are updated. More precisely, **bsDeLimitUpdate** == 1 means that the values **bsDeLimitFgo**, **bsDeLimitFgoEAO**, **bsDeLimitBgo,** and **bsDeLimitBgoEAO** are updated in the current frame, whereas **bsDeLimitUpdate** == 0 means that the previously transmitted values are kept.

bsDeLimitEaoUpdate Defines whether the values **bsDeLimitFgoEAO** and **bsDeLimitBgoEAO** are updated. More precisely, **bsDeLimitEaoUpdate** == 1 means that the values **bsDeLimitFgoEAO** and **bsDeLimitBgoEAO** are updated in the current frame,

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whereas **bsDeLimitEaoUpdate** == 0 means that the previously transmitted values are kept.

EcDataSaoc() Syntactic element that contains all parameter subsets of a given parameter in the SAOC frame. However, the changes described in Table 46 and Table 47 apply.

Table 46 — lavTabXXXdf

LavIdx	lavTabDCLD/DMG/PDGdf [LavIdx]	lavTabIOCdf [LavIdx]	lavTabOLDdf [LavIdx]	lavTabNRGdf [LavIdx]
0	3	1	3	3
1	5	3	6	5
2	7	5	9	7
3	9	7	12	9
NOTE This table replaces ISO/IEC 23003-1:2007, Table 76 and shall be applied only in case diffType == DIFF_FREQ.				

Table 47 — lavTabXXXdt

LavIdx	lavTabDCLD/DMG/PDGdt [LavIdx]	lavTabIOCdt [LavIdx]	lavTabOLDdt [LavIdx]	lavTabNRGdt [LavIdx]
0	3	1	3	3
1	5	3	6	6
2	7	5	9	9
3	9	7	12	12
NOTE This table replaces ISO/IEC 23003-1:2007, Table 76 and shall be applied only in case diffType == DIFF_TIME.				

SAOCEcDataPair() Syntactic element that contains one or two temporally subsequent parameter subsets of a given parameter in the SAOC frame.

SAOCDiffHuffData() Syntactic element that contains one or two temporally subsequent parameter subsets of a given parameter in the SAOC frame, where the quantized values are coded using a combination of differential coding and Huffman coding.

bsPcmCodingXXX Indicates whether PCM coding is applied.

GroupedPcmData() Syntactic element that contains one or two temporally subsequent parameter subsets of a given parameter in the SAOC frame, where groups of quantized values are represented by a single PCM code. numQuantSteps depends on the data type XXX and whether coarse or fine quantization is used and is defined in Table 48.

Table 48 — numQuantSteps

XXX (dataType)	numQuantStepsXXXCoarse	numQuantStepsXXXFine
DCLD, DMG, PDG	15	31
IOC	4	8
OLD	8	16
NRG	32	64

SAOCExtensionConfig() Syntactic element that acts as container to carry extensions to the SAOC audio configuration. The presence of the SAOC extension of type **bsSaocExtType** (see Table 49) is signaled by the presence of a SAOCExtensionConfigData(**bsSaocExtType**) element in SAOCExtensionConfig().

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SaocExtNum — Helper variable storing the number of the SAOC extension containers present.

bsSaocExtType — Indicates type of the SAOC extension data according to Table 49.

Table 49 — bsSaocExtType

bsSaocExtTyp	Meaning	SAOCExtensionFrameData()
0	Residual coding data	present
1	Dynamic preset information	
2	MBO MPS data	
3	Dynamic object metadata	
4...7	N/A	
8	Static object metadata	not present
9	Static preset information	
10	Separation metadata	
11...15	N/A	

SaocExtType[i] — Helper variable storing the type of spatial extension data carried in the extension container *i*.

bsSaocExtLen — Number of bytes in SAOCExtensionConfigData() or SAOCExtensionFrameData().

bsSaocExtLenAdd — Additional number of bytes in SAOCExtensionConfigData() or SAOCExtensionFrameData().

bsSaocExtLenAddAdd — Further additional number of bytes in SAOCExtensionConfigData().

bsFillBits — Fill bits, to be ignored.

SAOCExtensionConfigData(**bsSacExtType**)
Instance of the SAOCExtensionConfigData that carries configuration data for the SAOC extension of type **bsSaocExtType** (see Table 49).

SAOCExtensionConfigData(0)
Syntactic element that, if present, indicates that modification range control information (in case of SAOC-DE profile), residual coding information, and corresponding DCU parameters are available.

SAOCExtensionConfigData(1)
Syntactic element that, if present, indicates that dynamic preset information is available.

SAOCExtensionConfigData(2)
Syntactic element that, if present, indicates that the MBO MPS data is available.

SAOCExtensionConfigData(3)
Syntactic element that, if present, indicates that dynamic object metadata is available.

SAOCExtensionConfigData(8)
Syntactic element that, if present, indicates that metadata information is available.

SAOCExtensionConfigData(9)
Syntactic element that, if present, indicates that static preset information is available.

SAOCExtensionConfigData(10)
Syntactic element that, if present, indicates that separation metadata is available.

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SeparationMetaData()
Syntactic element that contains a metadata description of the separated objects.

bsNumSeparationPairs
Defines the number of pairs of the separated objects.

bsSeparationMainObjectID[i]
Defines the object ID of the main object which is separated from mixed signals. Its value is in the range of 0 to **bsNumObjects**.

bsSeparationSubObjectID[i]
Defines the object ID of the sub object which is separated from mixed signals. Its value is in the range of 0 to **bsNumObjects**.

PresetConfig() Syntactic element that contains all preset rendering data.

bsNumPresets Defines the number of available rendering presets.

bsNumBytePresetLabel[i]
Defines the number of bytes used for the text label of the preset *i*.

bsPresetLabel[i][j] Defines the text label for the preset *i* (interpreted as a string in UTF-8 encoding format).

bsPresetMatrix Defines the preset data representation type according to Table 50.

Table 50 — bsPresetMatrix

bsPresetMatrix	Meaning
0	User-defined preset representation format
1	Matrix-based preset representation format

PresetMatrixData() Syntactic element that contains the preset rendering parameters in the matrix-based representation format.

bsPresetMatrixType Defines the rendering configuration according to Table 51.

Table 51 — bsPresetMatrixType

bsPresetMatrixType	Meaning
0	Mono playback system
1	Stereo playback system
2	5.1 playback system
3	3.0 playback system

PresetMatrixType[**bsPresetMatrixType**]
Defines the number of upmix channels according to Table 52.

Table 52 — PresetMatrixType

bsPresetMatrixType	0	1	2	3
PresetMatrixType**[bsPresetMatrixType]**	1	2	5	N/A

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bsPresetMatrixElements[i][j]

Defines the preset rendering matrix. Namely, the output level of the audio object channel *i* for the upmix channel *j*.

PresetUserData() Syntactic element that contains the preset rendering parameters in the user-defined preset representation format.

bsPresetUserDataIdentifier[i]

Defines the identifier for the user-defined preset *i* representation format (interpreted as a string in UTF-8 encoding format).

bsPresetUserDataLen Defines the length in bytes for the preset data included into PresetUserDataContainer() container element.

PresetUserDataContainer()

Syntactic element that contains preset rendering data in the user-defined preset representation format and has a length of exactly **bsPresetUserDataLen** bytes.

All bitstream variables which are not explicitly described here are defined in ISO/IEC 23003-1. Any modifications and amendments to these definitions are specified in Annex A.

7 SAOC processing

7.1 Compressed data stream decoding and dequantization of SAOC data

7.1.1 General

This subclause describes the decoding and dequantization of the bitstream payload into variables that are used in the SAOC transcoder/decoder.

7.1.2 Dequantization of the SAOC parameters

The dequantization of the IOC parameters follows the same rules as defined in ISO/IEC 23003-1:2007, 6.1.8 for the MPS ICC parameters, the decoding of the DMG, DCLD and PDG parameters those of the MPS CLD parameters.

The dequantization of the OLD (i.e. relative energy) parameters is done by applying the dequantization function *deq(index, parameterType)* as defined in ISO/IEC 23003-1:2007, 6.1.8 in combination with the parameter quantization table given in Table 53.

Table 53— OLD parameter quantization table

idx	0	1	2	3	4	5	6	7
OLD[idx]	$10^{-15.0}$	$10^{-4.5}$	$10^{-4.0}$	$10^{-3.5}$	$10^{-3.0}$	$10^{-2.5}$	$10^{-2.2}$	$10^{-1.9}$
idx	8	9	10	11	12	13	14	15
OLD[idx]	$10^{-1.6}$	$10^{-1.3}$	$10^{-1.0}$	$10^{-0.8}$	$10^{-0.6}$	$10^{-0.4}$	$10^{-0.2}$	1

The dequantization of the NRG (i.e. absolute energy) parameters is done by applying the dequantization function *deq(index, parameterType)* as defined in ISO/IEC 23003-1:2007, 6.1.8 in combination with the parameter quantization table given in Table 54.

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Table 54 — NRG parameter quantization table

idx	0	1	2	3	4	5	6	7
NRG[idx]	$50 \cdot 10^{-9.45}$	$50 \cdot 10^{-9.30}$	$50 \cdot 10^{-9.15}$	$50 \cdot 10^{-9.00}$	$50 \cdot 10^{-8.85}$	$50 \cdot 10^{-8.70}$	$50 \cdot 10^{-8.55}$	$50 \cdot 10^{-8.40}$
idx	8	9	10	11	12	13	14	15
NRG[idx]	$50 \cdot 10^{-8.25}$	$50 \cdot 10^{-8.10}$	$50 \cdot 10^{-7.95}$	$50 \cdot 10^{-7.80}$	$50 \cdot 10^{-7.65}$	$50 \cdot 10^{-7.50}$	$50 \cdot 10^{-7.35}$	$50 \cdot 10^{-7.20}$
idx	16	17	18	19	20	21	22	23
NRG[idx]	$50 \cdot 10^{-7.05}$	$50 \cdot 10^{-6.90}$	$50 \cdot 10^{-6.75}$	$50 \cdot 10^{-6.60}$	$50 \cdot 10^{-6.45}$	$50 \cdot 10^{-6.30}$	$50 \cdot 10^{-6.15}$	$50 \cdot 10^{-6.00}$
idx	24	25	26	27	28	29	30	31
NRG[idx]	$50 \cdot 10^{-5.85}$	$50 \cdot 10^{-5.70}$	$50 \cdot 10^{-5.55}$	$50 \cdot 10^{-5.40}$	$50 \cdot 10^{-5.25}$	$50 \cdot 10^{-5.10}$	$50 \cdot 10^{-4.95}$	$50 \cdot 10^{-4.80}$
idx	32	33	34	35	36	37	38	39
NRG[idx]	$50 \cdot 10^{-4.65}$	$50 \cdot 10^{-4.50}$	$50 \cdot 10^{-4.35}$	$50 \cdot 10^{-5.20}$	$50 \cdot 10^{-4.05}$	$50 \cdot 10^{-3.90}$	$50 \cdot 10^{-3.75}$	$50 \cdot 10^{-3.60}$
idx	40	41	42	43	44	45	46	47
NRG[idx]	$50 \cdot 10^{-3.45}$	$50 \cdot 10^{-3.30}$	$50 \cdot 10^{-3.15}$	$50 \cdot 10^{-3.00}$	$50 \cdot 10^{-2.85}$	$50 \cdot 10^{-2.70}$	$50 \cdot 10^{-2.55}$	$50 \cdot 10^{-2.40}$
idx	48	49	50	51	52	53	54	55
NRG[idx]	$50 \cdot 10^{-2.25}$	$50 \cdot 10^{-2.10}$	$50 \cdot 10^{-1.95}$	$50 \cdot 10^{-1.80}$	$50 \cdot 10^{-1.65}$	$50 \cdot 10^{-1.50}$	$50 \cdot 10^{-1.35}$	$50 \cdot 10^{-1.20}$
idx	56	57	58	59	60	61	62	63
NRG[idx]	$50 \cdot 10^{-1.05}$	$50 \cdot 10^{-0.90}$	$50 \cdot 10^{-0.75}$	$50 \cdot 10^{-0.60}$	$50 \cdot 10^{-0.45}$	$50 \cdot 10^{-0.30}$	$50 \cdot 10^{-0.15}$	50

The decoding of the SAOCFrame() data or SAOCDEFrame() data results in the parameter indices idxXXX of the quantized OLD, IOC, NRG, DCLD, DMG and PDG parameters that are listed in Table 55, where

$$pi = 0 \ldots N-1, \quad ps = 0 \ldots L-1, \quad pb = 0 \ldots M_{proc}-1, \quad pd = 0 \ldots M-1.$$

Table 55 — Dimensions and value ranges of the parameter indices idxXXX

Parameter	idxOLD	idxNRG	idxIOC	idxDMG	idxDCLD	idxPDG
Dimension	[pi][ps][pb]	[ps][pb]	[pi][pi][ps][pb]	[ps][pi]	[ps][pi]	[ps][pb][pd]
Value range	0 ... 15	0 ... 63	0 ... 7	-15 ... 15	-15 ... 15	-15 ... 15

The decoding follows largely the procedure described in ISO/IEC 23003-1, taking into account the following differences. The pseudo code defining the preprocessing step in ISO/IEC 23003-1:2007, 6.1.2.3.2 is altered in the following way:

```
setIdxStart = dataSetIdx[ps];
startBand = startBandXXX[pi];
stopBand = stopBandXXX[pi];
pbStride = pbStrideTable[bsFreqResStrideXXX[pi][setIdx]];
dataBands = (stopBand - startBand - 1)/pbStride + 1; /*ANSI C integer
math*/
aGroupToBand = createMapping(startBand, stopBand, pbStride);
for (pg=0; pg<dataBands; pg++) {
    pb = aGroupToBand[pg];
    tmp = idxXXX[pi][ps-1][pb];
    switch (XXX) {
    case DCLD, DMG:
        if (bsQuantCoarseXXX[pi][setIdx]) {
            tmp = (tmp/2)+7;    /* ANSI C integer math */
        }
        else {
            tmp = tmp+15;
        }
        break;
    case IOC:
        if (bsQuantCoarseXXX[pi][setIdx]) {
            tmp = tmp/2;    /* ANSI C integer math */
```

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```
        }
        break;
    case OLD:
        if (bsQuantCoarseXXX[pi][setIdx]) {
            tmp = tmp/2;    /* ANSI C integer math */
        }
        break;
    case NRG:
        if (bsQuantCoarseXXX[pi][setIdx]) {
            tmp = tmp/2;    /* ANSI C integer math */
        }
        break;
    }
    idxXXXmsb[pi][setIdxStart-1][pg] = tmp;
}
```

The pseudo code defining the postprocessing step in ISO/IEC 23003-1:2007, 6.1.2.3.2 is altered in the following way:

```
for (i=0; i<=bsDataPairXXX[pi][setIdxStart]; i++) {
    setIdx = setIdxStart+i;
    ps = paramSet[setIdx];
    paramHandled[ps] = 1;
    for (pg=0; pg<dataBands; pg++) {
        tmp = idxXXXnotMapped[pi][setIdx][pg];
        switch (XXX) {
        case DCLD, DMG:
            if (bsQuantCoarseXXX[pi][setIdx]) {
                tmp = (tmp-7)*2;
                if (tmp==-14) tmp=-15;
                if (tmp==14) tmp=15;
            }
            else {
                tmp = tmp-15;
            }
            break;
        case IOG:
            if (bsQuantCoarseXXX[pi][setIdx]) {
                tmp = tmp*2;
            }
            break;
        case OLD:
            if (bsQuantCoarseXXX[pi][setIdx]) {
                if ( tmp > 0 ) {
                    tmp = tmp*2 + 1;
                }
            }
            break;
        case NRG:
            if (bsQuantCoarseXXX[pi][setIdx]) {
                tmp = tmp*2;
            }
            break;

        }
```

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```
            pbStart = aGroupToBand[pg];
            pbStop = aGroupToBand[pg+1];
            for (pb=pbStart; pb<pbStop; pb++) {
                idxXXX[pi][ps][pb] = tmp;
            }
        }
    }
```

The pseudo code in ISO/IEC 23003-1:2007, 6.1.2.2 is altered in the following way:

```
while (ps=0; ps<numParamSet; ps++) {
switch (bsXXXdataMode[pi][ps]) {
case 0: /* default */
    for (pb=0; pb<numBands, pb++) {
        switch (XXX) {
        case NRG, DCLD, DMG:
            idxXXX[pi][ps][pb] = 0;
            break;
        }
        case OLD:
            idxXXX[pi][ps][pb] = 15;
            break;
        }
        case IOC:
            idxXXX[pi][ps][pb] = 5;
            break;
        }

    break;
case 1: /* keep */
case 2: /* interpolate */
    for (pb=0; pb<numBands, pb++) {
        idxXXX[pi][ps][pb] = idxXXX[pi][ps-1][pb];
    }
    break;
case 3: /* coded */
    if (!paramHandled[ps]) {
        DecodeDataPair(); /*see subclause 6.1.2.3 in ISO/IEC 23003- 1:2007*/
    }
    break;
}
}
```

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7.2 Compressed data stream encoding and quantization of MPS data

7.2.1 General

This subclause describes the encoding and quantization of the variables into bitstream payload that are used in the MPS decoder.

7.2.2 Quantization of the MPS parameters

The obtained CLD (ADG), ICC and CPC parameters are quantized according to ISO/IEC 23003-1:2007, Tables 82, 83 and 84. The delta and Huffman coding corresponds the description given in ISO/IEC 23003-1:2007, Clause 6.

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7.2.3 Unquantized interface for the MPS parameters

For an efficient practical implementation and to prevent a loss in precision, the parameter interface to the MPS decoder may alternatively be established in a direct, unquantized way. The required range of all relevant parameters is determined by the minimal and maximal values of the corresponding dequantization scheme. Rather than writing an actual MPS bitstream, the relevant parameters may be passed directly using binary32 (single) floating point format (IEEE 754-2008) to the MPS decoder.

7.2.4 List of MPS bitstream variables

Table 56 contains the list of all MPS bitstream variables (with the corresponding references to tables defined in ISO/IEC 23003-1) which are needed to be specified for the MPS bitstream generation and their values.

Table 56 — List of MPS bitstream variables

MPS bitstream variable	Value/SAOC bitstream variable/description	Reference[a]
bsSamplingFrequencyIndex	bsSamplingFrequencyIndex	Table 5
bsSamplingFrequency	bsSamplingFrequency	Table 5
bsFrameLength	bsFrameLength	Table 5
bsFreqRes	bsFreqRes	Table 5
bsTreeConfig	0 (for mono downmix) / 2 (for stereo downmix)	Table 5
bsQuantMode	0	Table 5
bsOneIcc	0	Table 5
bsArbitraryDownmix	1 (for mono downmix) / 0 (for stereo downmix)	Table 5
bsFixedGainsSur	0	Table 5
bsFixedGainsLFE	0	Table 5
bsFixedGainsDMX	0	Table 5
bsMatrixMode	0	Table 5
bsTempShapeConfig	0	Table 5
bsDecorrConfig	0	Table 5
bs3DaudioMode	0	Table 5
bsOttBands[0]	The number of parameter bands for LFE channel for which OTT information is present	Table 7
bsTttDualMode[0]	bsTttDualMode	Table 8
bsTttModeLow[0]	1	Table 8
bsTttModeHigh[0]	5	Table 8
bsTttBandsLow[0]	bsTttBandsLow	Table 8
FramingInfo()	SAOCFramingInfo()	Table 16
bsIndependencyFlag	Indicates if lossless coding of current frame is done independently of previous frame	Table 16
bsSmoothMode	0	Table 20

[a] Defined in ISO/IEC 23003-1.

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7.3 Time/frequency transforms

The same hybrid filterbank as described in ISO/IEC 23003-1 is applied.

7.4 Signals and parameters

7.4.1 Dimensionality of signals and parameters

The audio signals are defined for every time slot, n, and every hybrid subband, k. The corresponding SAOC parameters are defined for each parameter time slot, l, and processing band, m. The subsequent mapping between the hybrid and parameter domain is specified by ISO/IEC 23003-1:2007, Table A.31.

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The linear interpolation processing step is applied for the parametric up-mixing matrices (**G** and $\mathbf{P}_2$); EAO processing matrices ($\mathbf{A}_{EAO}$ and **M**); SAOC-DE processing matrices ($\mathbf{G}_{DE}$ and $\mathbf{M}_{DE}$) and downmix post(processing) compensation matrix ($\mathbf{W}_{PDG}$); according to the procedure specified in ISO/IEC 23003-1:2007, 6.5.2.1. Hence, all calculations are performed with respect to the certain time/band indices and the corresponding dimensionalities are implied for each introduced variable.

The data available at the SAOC decoder/transcoder consists of the downmix signal **X**, covariance matrix **E**, rendering matrix, $\mathbf{M}_{ren}$, and downmix matrix, **D**.

7.4.2 Input signal

The input signal **X** to the SAOC decoder/transcoder is represented as

$$\mathbf{X} = \begin{pmatrix} x_0 \\ \dots \\ x_{M-1} \end{pmatrix}, \text{for SAOC-DE downmix channel configurations,}$$

$$\mathbf{X} = \begin{pmatrix} l_0 \\ r_0 \end{pmatrix}, \quad \text{for stereo downmix, and}$$

$$\mathbf{X} = \begin{pmatrix} d_0 \\ 0 \end{pmatrix}, \quad \text{for mono downmix.}$$

7.4.3 Post(processing) downmix compensation

7.4.3.1 General

If the post(processed) downmix $\mathbf{X}_{post(processed)}$ compensation is applied (**bsPdgFlag** == 1), the following modification should be taken prior to the SAOC decoding/transcoding

$$\mathbf{X} = \mathbf{W}_{PDG}\mathbf{X}_{post(processed)}.$$

The matrix $\mathbf{W}_{PDG}$ is obtained from the transmitted PDG parameters as

$$\mathbf{W}_{PDG} \begin{pmatrix} PDG_0 & \dots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \dots & PDG_{M-1} \end{pmatrix}, \quad \text{for SAOC-DE profile,}$$

$$\mathbf{W}_{PDG} \begin{pmatrix} PDG_0 & 0 \\ 0 & PDG_1 \end{pmatrix}, \quad \text{for stereo downmix, and}$$

$$\mathbf{W}_{PDG} \begin{pmatrix} PDG_0 & 0 \\ 0 & 0 \end{pmatrix}, \quad \text{for mono downmix.}$$

Here, the dequantized post(processed) downmix gains are obtained according to 7.1.2 as

$$PDG_j = \mathbf{D}_{PDG}(j,l,m).$$

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7.4.3.2 Post(processing) re-application

If the post(processed) downmix compensation is applied (**bsPdgFlag** == 1) for the SAOC-DE profile, the following modification should be taken after the SAOC processing

$$\hat{\mathbf{X}}_{\text{post(processed)}} = \mathbf{W}_{\text{PDG}}^{-1}\hat{\mathbf{X}},$$

where

$$\mathbf{W}_{\text{PDG}}^{-1} = \begin{pmatrix} \frac{1}{\mathbf{W}_{\text{PDG}}(0,0)} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \frac{1}{\mathbf{W}_{\text{PDG}}(M-1,M-1)} \end{pmatrix}.$$

7.4.4 Object parameters

The covariance matrix **E** of size $N \times N$ with elements $e_{i,j}$ represents an approximation of the original signal covariance matrix $\mathbf{E} \approx \mathbf{SS}^*$ and is obtained from the OLD and IOC parameters as

$$e_{i,j} = \sqrt{OLD_i OLD_j}\, IOC_{i,j}.$$

Here, the dequantized object parameters are obtained according to 7.1.2 as

$$OLD_i = \mathbf{D}_{\text{OLD}}(i,l,m), \quad IOC_{i,j} = \mathbf{D}_{\text{IOC}}(i,j,l,m).$$

7.4.5 Rendering matrix

7.4.5.1 General

The rendering matrix, $\mathbf{M}_{\text{ren}}$, applied to the input audio objects, **S**, determines the target rendered output as $\mathbf{Y} = \mathbf{M}_{\text{ren}}\mathbf{S}$. The rendering matrix, $\mathbf{M}_{\text{ren}}$, with elements $m_{j,i}$ maps all input objects, i, to the desired output channels j.

7.4.5.2 Rendering matrix for baseline and LD profiles

The rendering matrix, $\mathbf{M}_{\text{ren}}$, is given by

$$\mathbf{M}_{\text{ren}} \begin{pmatrix} m_{L,0} & \cdots & m_{L,N-1} \\ m_{R,0} & \cdots & m_{R,N-1} \\ m_{C,0} & \cdots & m_{C,N-1} \\ m_{LFE,0} & \cdots & m_{LFE,N-1} \\ m_{Ls,0} & \cdots & m_{Ls,N-1} \\ m_{Rs,0} & \cdots & m_{Rs,N-1} \end{pmatrix}, \text{ for 5.1 output configuration,}$$

$$\mathbf{M}_{\text{ren}} \begin{pmatrix} m_{L,0} & \cdots & m_{L,N-1} \\ m_{R,0} & \cdots & m_{R,N-1} \end{pmatrix}, \text{ for stereo output configuration, and}$$

$$\mathbf{M}_{\text{ren}} \begin{pmatrix} m_{C,0} & \cdots & m_{C,N-1} \end{pmatrix}, \text{ for mono output configuration.}$$

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7.4.5.3 Binaural rendering matrix

The binaural rendering matrix **A** of size $2 \times N$ with elements $a_{L,i}$ and $a_{R,i}$ maps all the input objects i to the desired left L and right R binaural output channels j. The binaural rendering matrix $\mathbf{A}$ is given by

$$\mathbf{A} = \begin{pmatrix} a_{L,0} & \cdots & a_{L,N-1} \\ a_{R,0} & \cdots & a_{R,N-1} \end{pmatrix}.$$

The binaural rendering matrix $\mathbf{A}$ is derived from the head related transfer function (HRTF) parameters, $P_{k,L}^{\mathrm{HRTF}}$, $P_{k,R}^{\mathrm{HRTF}}$ and ϕ_k^{HRTF} (described in ISO/IEC 23003-1) and the rendering matrix, $\mathbf{M}_{\mathrm{ren}}$, as

$$a_{L,i} = \sum_{k=0}^{N_{\mathrm{HRTF}}-1} m_{k,i} P_{k,L}^{\mathrm{HRTF}} \exp\left(-j\frac{\phi_k^{\mathrm{HRTF}}}{2}\right), \; a_{R,i} = \sum_{k=0}^{N_{\mathrm{HRTF}}-1} m_{k,i} P_{k,R}^{\mathrm{HRTF}} \exp\left(-j\frac{\phi_k^{\mathrm{HRTF}}}{2}\right),$$

where the spatial positions for which the HRTF parameters are available are characterized by the index k. The variable j represents here an imaginary number.

7.4.5.4 Rendering matrix for SAOC-DE profile

Object rendering matrix, $\mathbf{M}_{\mathrm{ren}}$, for the SAOC-DE profile can be represented as a function of two gains m_{BGO} (for BGOs) and m_{FGO} (for FGOs) which can be specified by one scalar input value m_{G}.

$\mathbf{M}_{\mathrm{ren}} = \begin{pmatrix} m_{0,1} & \ldots & m_{0,N-1} \\ \ldots & \ldots & \ldots \\ m_{M-1,0} & \ldots & m_{M-1,N-1} \end{pmatrix}$, for SAOC-DE output channel configurations,

determined as

$$\mathbf{M}_{\mathrm{ren}} = \begin{pmatrix} m_{\mathrm{BGO}}\mathbf{D}_{\mathrm{BGO}} & m_{\mathrm{FGO}}\mathbf{D}_{\mathrm{FGO}} \end{pmatrix},$$

where

$m_{\mathrm{FGO}} = m_{\mathrm{G}}$ and $m_{\mathrm{BGO}} = 1$, if $m_{\mathrm{G}} \le 1$,

$m_{\mathrm{FGO}} = 1$ and $m_{\mathrm{BGO}} = m_{\mathrm{G}}^{-1}$, if $m_{\mathrm{G}} > 1$.

7.4.6 Downmix matrix

7.4.6.1 General

The downmix matrix **D** applied to the input audio objects **S** determines the downmix signal as $\mathbf{X} = \mathbf{DS}$.

7.4.6.2 Downmix matrix for baseline and LD profiles

For the stereo downmix case, the downmix matrix **D** of size $2 \times N$ with elements $d_{i,j}$ $(i = 0,1;\ j = 0,\cdots, N-1)$ is obtained from the DMG and DCLD parameters as

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$$d_{0,j} = 10^{0.05 DMG_j} \sqrt{\frac{10^{0.1 DCLD_j}}{1+10^{0.1 DCLD_j}}},\ d_{1,j} = 10^{0.05 DMG_j} \sqrt{\frac{1}{1+10^{0.1 DCLD_j}}}.$$

For the mono downmix case, the downmix matrix **D** of size $1 \times N$ with elements $d_{i,j}$ $(i=0;\ j=0,\ldots,N-1)$ is obtained from the DMG parameters as

$$d_{0,j} = 10^{0.05 DMG_j}.$$

Here, the dequantized downmix parameters are obtained according to 7.1.2 as

$$DMG_j = \mathbf{D}_{\mathrm{DMG}}(j,l), \qquad DCLD_j = \mathbf{D}_{\mathrm{DCLD}}(j,l).$$

7.4.6.3 Downmix matrix for SAOC-DE profile

For the SAOC-DE output channel configurations, the downmix matrix **D** of size $M \times N$ with elements $d_{i,j}$ $(i=0,\ldots,M-1;\ j=0,\ldots,N-1)$ is obtained from the DMG parameters as

$$d_{i,j} = 10^{0.05 DMG_{i,j}}.$$

The downmix matrix has the following structure:

$$\mathbf{D} = \begin{pmatrix} \mathbf{D}_{\mathrm{BGO}} & \mathbf{D}_{\mathrm{FGO}} \end{pmatrix}.$$

The matrix $\boldsymbol{D}_{\mathrm{BGO}}$ of size $M \times (N - N_{\mathrm{FGO}})$ corresponds to the background and $\boldsymbol{D}_{\mathrm{FGO}}$ of size $M \times N_{\mathrm{FGO}}$ corresponds to the foreground objects.

Here, the dequantized downmix parameters are obtained according to 7.1.2 as

$$DMG_{i,j} = \mathbf{D}_{\mathrm{DMG}}(i,j,l).$$

7.4.7 Input covariance

The input covariance v is given as

$$v = \mathbf{D}\mathbf{E}\mathbf{D}^* + \varepsilon^2.$$

7.4.8 Output covariance

The output covariance matrix **F** with elements $f_{i,j}$ is given as

$$\mathbf{F} = \mathbf{A}\mathbf{E}\mathbf{A}^*, \qquad \text{for binaural rendering,}$$

$$\mathbf{F} = \mathbf{M}_{\mathrm{ren}}\mathbf{E}\mathbf{M}_{\mathrm{ren}}^*, \qquad \text{otherwise.}$$

7.5 SAOC transcoding/decoding modes for baseline and LD profiles

7.5.1 Overview

The general structure of the SAOC transcoding/decoding modes consists of two signal paths (see Figure 13).

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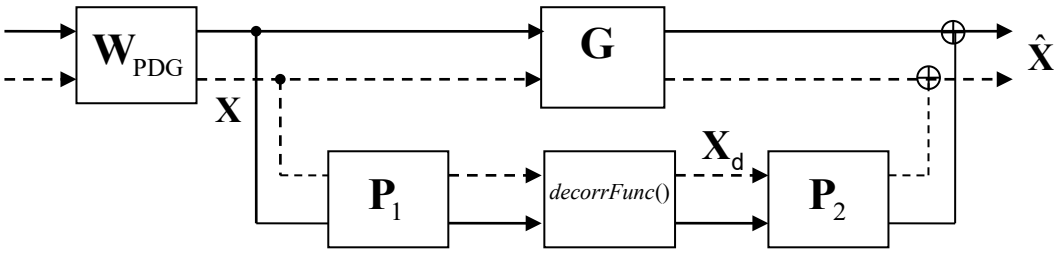

Figure 13 — Basic structure for the SAOC transcoding/decoding modes

The output signal of the SAOC transcoder/decoder is produced by the corresponding mixing of a modified downmix signal and a processed decorrelated signal component as follows:

$$\hat{\mathbf{X}} = \mathbf{G}\mathbf{X} + \mathbf{P}_2\mathbf{X}_d.$$

7.5.2 Decorrelated signal

The decorrelated signal, $\mathbf{X}_d$, is obtained by using the decorrelator function *decorrFunc*() described in ISO/IEC 23003-1:2007, 6.6.2. Following this scheme, the **bsDecorrConfig** == 0 configuration is used with a decorrelator index X == 8, according to ISO/IEC 23003-1:2007, Tables A.26 to A.29. Hence, the signal, $\mathbf{X}_d$, is computed according to

$$\mathbf{X}_d = \begin{pmatrix} decorrFunc\left(\begin{pmatrix}1 & 0\end{pmatrix}\mathbf{P}_1\mathbf{X}\right) \\ decorrFunc\left(\begin{pmatrix}0 & 1\end{pmatrix}\mathbf{P}_1\mathbf{X}\right) \end{pmatrix}.$$

7.5.3 Transcoding modes

7.5.3.1 General

In this subclause, the method for converting of SAOC parameters and panning information associated with each audio object into a standard compliant MPS bitstream is explained. The SAOC transcoder consists of the SAOC parameter processing unit and the downmix preprocessor [see Figure 2 (left)].

The MPS decoder employs a tree-structured parameterization. The corresponding tree-structures consist of OTT elements that split each mono input into two output signals and TTT elements that split each stereo input into three output signals (see Figure 14).

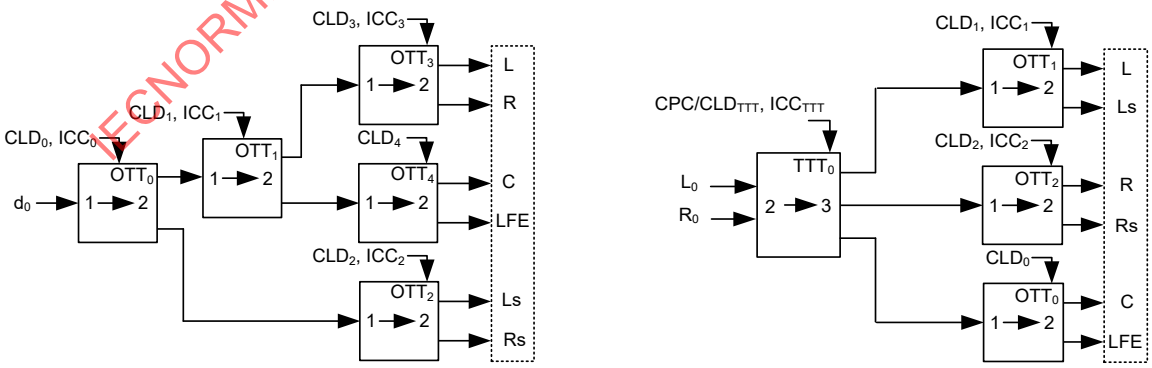

Figure 14 — Tree structure for the MPS decoder for mono downmix (left) and stereo downmix (right)

The channel level difference (CLD) and inter-channel correlation (ICC) parameters associated with each OTT element describe the relative level differences and cross-correlation between two output channels,

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correspondently. The channel prediction coefficient (CPC) parameters associated with TTT box represent prediction coefficients needed for reconstruction of the third output signal from two input ones. The arbitrary downmix gains (ADG) parameters describe the modification of the downmix signal.

7.5.3.2 Mono downmix ("x-1-5") processing mode

7.5.3.2.1 General

The following subclauses describe the processing steps dedicated to the transformation of SAOC parameters (OLD, IOC, DMG) into MPS data (CLD, ICC, ADG) according to the rendering information for the mono downmix case [see Figure 14 (left)]. The downmix signal is not modified.

7.5.3.2.2 SAOC downmix preprocessor unit

The SAOC downmix processor does not perform any downmix modification:

$$\mathbf{G} = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}, \qquad \mathbf{P}_1 = \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}.$$

In order to achieve not only a repanning of the objects but also object attenuation/amplification functionality with an MPS renderer, the ADG parameters are used for a "virtual" modification of the downmix signal energy.

7.5.3.2.3 SAOC parameter processing unit

The respective contribution of each object to the two outputs of OTT_h element is obtained by summation of the corresponding elements in the rendering matrix, $\mathbf{M}_{ren}$. The subsequent sub-rendering matrices $\mathbf{W}_h$ with elements $w_{i,j}^h$ are defined as

$$\mathbf{W}_0^{l,m} = \begin{pmatrix} w_{0,0}^0 & \cdots & w_{0,N-1}^0 \\ w_{1,0}^0 & \cdots & w_{1,N-1}^0 \end{pmatrix} =$$

$$= \begin{pmatrix} \sqrt{\left(m_{L,0}^{l,m}\right)^2 + \left(m_{R,0}^{l,m}\right)^2 + \left(m_{C,0}^{l,m}\right)^2 + \left(m_{LFE,0}^{l,m}\right)^2} & \cdots & \sqrt{\left(m_{L,N-1}^{l,m}\right)^2 + \left(m_{R,N-1}^{l,m}\right)^2 + \left(m_{C,N-1}^{l,m}\right)^2 + \left(m_{LFE,N-1}^{l,m}\right)^2} \\ \sqrt{\left(m_{Ls,0}^{l,m}\right)^2 + \left(m_{Rs,0}^{l,m}\right)^2} & \cdots & \sqrt{\left(m_{Ls,N-1}^{l,m}\right)^2 + \left(m_{Rs,N-1}^{l,m}\right)^2} \end{pmatrix}$$

$$\mathbf{W}_1^{l,m} = \begin{pmatrix} w_{0,0}^1 & \cdots & w_{0,N-1}^1 \\ w_{1,0}^1 & \cdots & w_{1,N-1}^1 \end{pmatrix} = \begin{pmatrix} \sqrt{\left(m_{L,0}^{l,m}\right)^2 + \left(m_{R,0}^{l,m}\right)^2} & \cdots & \sqrt{\left(m_{L,N-1}^{l,m}\right)^2 + \left(m_{R,N-1}^{l,m}\right)^2} \\ \sqrt{\left(m_{C,0}^{l,m}\right)^2 + \left(m_{LFE,0}^{l,m}\right)^2} & \cdots & \sqrt{\left(m_{C,N-1}^{l,m}\right)^2 + \left(m_{LFE,N-1}^{l,m}\right)^2} \end{pmatrix},$$

$$\mathbf{W}_2^{l,m} = \begin{pmatrix} w_{0,0}^2 & \cdots & w_{0,N-1}^2 \\ w_{1,0}^2 & \cdots & w_{1,N-1}^2 \end{pmatrix} = \begin{pmatrix} m_{Ls,0}^{l,m} & \cdots & m_{Ls,N-1}^{l,m} \\ m_{Rs,0}^{l,m} & \cdots & m_{Rs,N-1}^{l,m} \end{pmatrix},$$

$$\mathbf{W}_3^{l,m} = \begin{pmatrix} w_{0,0}^3 & \cdots & w_{0,N-1}^3 \\ w_{1,0}^3 & \cdots & w_{1,N-1}^3 \end{pmatrix} = \begin{pmatrix} m_{L,0}^{l,m} & \cdots & m_{L,N-1}^{l,m} \\ m_{R,0}^{l,m} & \cdots & m_{R,N-1}^{l,m} \end{pmatrix},$$

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$$\mathbf{W}_4^{l,m} = \begin{pmatrix} w_{0,0}^4 & \cdots & w_{0,N-1}^4 \\ w_{1,0}^4 & \cdots & w_{1,N-1}^4 \end{pmatrix} = \begin{pmatrix} m_{C,0}^{l,m} & \cdots & m_{C,N-1}^{l,m} \\ m_{LFE,0}^{l,m} & \cdots & m_{LFE,N-1}^{l,m} \end{pmatrix}$$

The superscript of the matrix elements, e.g. $w_{0,0}^h$, refers to the OTT element index.

The index *h* refers to the OTT_h element

$$CLD_h = 10\log_{10}\left(\frac{r_{0,0}^0}{r_{1,1}^h}\right), \qquad ICC_h = \frac{r_{0,1}^1}{\sqrt{r_{0,0}^h r_{1,1}^h}}.$$

The terms $r_{i,j}^h$ can be estimated as

$$r_{i,j}^h = \max\left(\sum_{n=0}^{N-1}\sum_{m=0}^{N-1} w_{i,n}^h w_{j,m}^h \; e_{n,m}, \varepsilon^2\right),$$

and then $\mathbf{D}_{\mathrm{CLD}}(h,l,m)$ and $\mathbf{D}_{\mathrm{ICC}}(h,l,m)$ are obtained as

$$\mathbf{D}_{\mathrm{CLD}}(h,l,m) = CLD_h \text{ and } \mathbf{D}_{\mathrm{ICC}}(h,l,m) = ICC_h.$$

In order to achieve not only a repanning of the objects but also an object attenuation/amplification with an MPS renderer, the arbitrary downmix gains (ADGs) can be used for a "virtual" modification of the downmix signal energy. The ADG is a logarithmic measure and based on the rendering matrix $\mathbf{A}^{l,m}$ and the object parameters (OLD, IOC and DMG):

$$ADG = 10\log_{10}\left(\max\left(\frac{trace(\mathbf{F})}{v}, \varepsilon^2\right)\right)$$

The corresponding ADG parameters are determined as

$$\mathbf{D}_{\mathrm{ADG}}(l,m) = ADG.$$

The obtained $\mathbf{D}_{\mathrm{ADG}}$, $\mathbf{D}_{\mathrm{CLD}}$ and $\mathbf{D}_{\mathrm{ICC}}$ parameters are fed into the MPS decoder.

7.5.3.3 Stereo downmix ("x-2-5") processing mode

7.5.3.3.1 General

The following subclauses give a description of the SAOC transcoding mode for the stereo downmix case. The object parameters (OLD, IOC, DMG, DCLD) from the SAOC bitstream are transcoded into spatial parameters (CLD, ICC, CPC) for the MPS bitstream according to the rendering information. The downmix is modified according to object parameters and rendering matrix.

The transcoding process can conceptually be divided into two parts. In one part, a three-channel rendering is performed to a left, right and center channel. In this stage, the parameters for the downmix modification as well as the prediction parameters for the TTT box for the MPS decoder are obtained. In

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the other part, the CLD and ICC parameters for the rendering between the front and surround channels (OTT parameters, left front – left surround, right front – right surround, center - LFE) are determined. This is illustrated in the right side of Figure 14.

7.5.3.3.2 SAOC downmix preprocessor unit

The SAOC downmix preprocessor unit modifies the downmix according to the MPS parameters derived from SAOC data and rendering information. The matrices $\mathbf{G}$, $\mathbf{P}_1$, and $\mathbf{P}_2$ of size 2 × 2 are given as

$$\mathbf{G} = \begin{cases} \mathbf{W}_g\hat{\mathbf{G}}, & r_{1,2} > \varepsilon^2, \\ \hat{\mathbf{G}}, & \text{otherwise.} \end{cases}$$

$$\mathbf{P}_1 = \begin{pmatrix} 1 & 1 \\ 0 & 0 \end{pmatrix}\hat{\mathbf{G}},$$

$$\mathbf{P}_2 = \begin{cases} \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}, & r_{1,2} > \varepsilon^2, \\ \mathbf{V}_R\mathbf{W}_d, & \text{otherwise.} \end{cases}$$

The matrix $\hat{\mathbf{G}}$ of size 2 × 2is given as

$$\hat{\mathbf{G}} = \mathbf{D}_{TTT}\mathbf{C}_3.$$

The render upmix error matrix $\mathbf{R}$ of size 2 × 2 with elements $r_{i,j}$ is defined as

$$\mathbf{R} = \mathbf{A}_{\text{diff}}\mathbf{E}\mathbf{A}_{\text{diff}}^*,$$

where

$$\mathbf{A}_{\text{diff}} = \mathbf{D}_{TTT}\mathbf{A}_3 - \hat{\mathbf{G}}\mathbf{D},$$

The covariance matrix $\hat{\mathbf{R}}$ of size 2 × 2 with elements $\hat{r}_{i,j}$ of the predicted signal is obtained as

$$\hat{\mathbf{R}} = \hat{\mathbf{G}}\mathbf{D}\mathbf{E}\mathbf{D}^*\hat{\mathbf{G}}^*.$$

To derive $\mathbf{V}_R$ and $\mathbf{W}_d$, the characteristic equation of $\mathbf{R}$ needs to be solved:

$\det(\mathbf{R} - \lambda_{1,2}\mathbf{I}) = 0$, giving the eigenvalues, λ_1 and λ_2.

The corresponding eigenvectors $\mathbf{v}_{R1}$ and $\mathbf{v}_{R2}$ of $\mathbf{R}$ can be calculated solving the equation system:

$$(\mathbf{R} - \lambda_{1,2}\mathbf{I})\mathbf{v}_{R1,R2} = 0.$$

Eigenvalues are sorted in descending ($\lambda_1 \geq \lambda_2$) order and the eigenvector corresponding to the larger eigenvalue is calculated according to the formula above. It is assured to lie in the positive x-plane (first element has to be positive). The second eigenvector is obtained from the first by a 90° rotation:

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$$\mathbf{R} = \left(\mathbf{v}_{R1}\mathbf{v}_{R2}\right)\begin{pmatrix}\lambda_1 & 0\\ 0 & \lambda_2\end{pmatrix}\left(\mathbf{v}_{R1}\mathbf{v}_{R2}\right)^{*}.$$

The matrix $\mathbf{R}_d$ of size 2 × 2 with elements $r^{d}_{i,j}$ is determined as

$$\mathbf{R}_d = \mathbf{P}_1\mathbf{D}\mathbf{E}\mathbf{D}^{*}\mathbf{P}_1^{*}.$$

The gain matrix $\mathbf{W}_g$ of size 2 × 2 can subsequently be calculated as

$$\mathbf{W}_g(i,j) = \begin{cases}\min\left(\max\left(\sqrt{\dfrac{\hat{r}_{i,i}+r_{i,i}}{\max\left(r_{i,i},\varepsilon^2\right)}},0\right),1.5\right), & i=j,\\ 0, & \text{otherwise.}\end{cases}$$

The gain matrix $\mathbf{W}_d$ of size 2×2 is determined as

$$\mathbf{W}_d(i,j) = \begin{cases}\min\left(\sqrt{\dfrac{\lambda_i^{R}}{\max\left(r^{d}_{i,i},\varepsilon^2\right)}},2\right), & i=j,\\ 0, & \text{otherwise}\end{cases}$$

and the matrix $\mathbf{V}_R$ is determined as

$$\mathbf{V}_R = \left(\mathbf{v}_{R1}\mathbf{v}_{R2}\right).$$

7.5.3.3.3 SAOC parameter processing unit

Rendering to left, right, and center channel

In this stage, the spatial parameters are determined that control the rendering to a left and right channel, consisting of front and surround signals. These parameters describe the prediction matrix of the TTT box for the MPS decoding $\mathbf{C}_{TTT}$ (CPC parameters for the MPS decoder) and the downmix converter matrix **G**.

$\mathbf{C}_{TTT}$ is the prediction matrix to obtain the target rendering from the modified downmix $\hat{\mathbf{X}}$:

$$\mathbf{C}_{TTT}\hat{\mathbf{X}} = \mathbf{C}_{TTT}\mathbf{G}\mathbf{X} \approx \mathbf{A}_3\mathbf{S}.$$

$\mathbf{A}_3$ is a reduced rendering matrix of size 3 × *N*, describing the rendering to the left, right, and center channel respectively. It is obtained as $\mathbf{A}_3 = \mathbf{D}_{36}\mathbf{M}_{ren}$ with the 6-to-3 partial downmix matrix $\mathbf{D}_{36}$ defined by

$$\mathbf{D}_{36} = \begin{pmatrix} w_1 & 0 & 0 & 0 & w_1 & 0\\ 0 & w_2 & 0 & 0 & 0 & w_2\\ 0 & 0 & w_3 & w_3 & 0 & 0\end{pmatrix}.$$

The partial downmix weights, w_p, p = 1,2,3 are adjusted such that the energy of downmix signal is equal to the sum of energies of its components, up to a limit factor:

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$$w_1 = \sqrt{\frac{f_{1,1} + f_{5,5}}{\max\left(f_{1,1} + f_{5,5} + 2f_{1,5}, \varepsilon^2\right)}},\ w_2 = \sqrt{\frac{f_{2,2} + f_{6,6}}{\max\left(f_{2,2} + f_{6,6} + 2f_{2,6}, \varepsilon^2\right)}},\quad w_3 = \sqrt{0.5},$$

where $f_{i,j}$ denote the elements of **F**.

For the estimation of the desired prediction matrix $\mathbf{C}_{TTT}$ and the downmix preprocessing matrix **G**, a prediction matrix $\mathbf{C}_3$ of size 3 × 2 leading to the target rendering is defined as

$$\mathbf{C}_3\mathbf{X} \approx \mathbf{A}_3\mathbf{S}.$$

Such a matrix is derived by considering the normal formulae:

$$\mathbf{C}_3\left(\mathbf{D}\mathbf{E}\mathbf{D}^*\right) \approx \mathbf{A}_3\mathbf{E}\mathbf{D}^*.$$

The solution to the normal formulae yields the best possible waveform match for the target output given the object covariance model. The matrices **G** and $\mathbf{C}_{TTT}$ are obtained by solving the system of formulae:

$$\mathbf{C}_{TTT}\mathbf{G} = \mathbf{C}_3,$$

where

$$\mathbf{C}_3 = \mathbf{A}_3\mathbf{E}\mathbf{D}^*\mathbf{J}.$$

The matrix $\mathbf{J}$ is determined as $\mathbf{J} \approx \mathbf{\Delta}^{-1}$ according to 7.5.4 with $\mathbf{\Delta} = \mathbf{D}\mathbf{E}\mathbf{D}^*$.

A weighting matrix $\mathbf{W}$ of size 2×2 is computed as

$$\mathbf{W}(i,j) = \begin{cases} \sum_{p=0}^{N-1} \mathbf{D}(i,p)\mathbf{E}(p,p), & i = j, \\ 0, & \text{otherwise.} \end{cases}$$

Since $\mathbf{C}_{TTT}$ is a function of the MPS prediction parameters c_1 and c_2 (as defined in ISO/IEC 23003-1:2007), $\mathbf{C}_{TTT}\mathbf{G} = \mathbf{C}_3$ is rewritten in the following way, to find the stationary point or points of the function

$$\Gamma\begin{pmatrix} \tilde{c}_1 \\ \tilde{c}_2 \end{pmatrix} = \mathbf{b},$$

with $\mathbf{\Gamma} = \left(\mathbf{D}_{TTT}\ \mathbf{C}_3\right)\mathbf{W}\left(\mathbf{D}_{TTT}\ \mathbf{C}_3\right)^*$ and $\mathbf{b} = \mathbf{B}\mathbf{v}$,

where $\mathbf{D}_{TTT} = \begin{pmatrix} 1 & 0 & 1 \\ 0 & 1 & 1 \end{pmatrix}$, $\mathbf{B} = \mathbf{D}_{TTT}\ \mathbf{C}_3\mathbf{W}\mathbf{C}_3^*$, and $\mathbf{v} = \begin{pmatrix} 1 \\ 1 \\ -1 \end{pmatrix}$.

If $\mathbf{\Gamma}$ does not provide a unique solution [$\det(\mathbf{\Gamma}) < 10^{-3}$], the point is chosen that lies closest to the point resulting in a TTT pass-through. As a first step, the row i of $\mathbf{\Gamma}$ is chosen $\boldsymbol{\gamma} = [\gamma_{i,1}\ \ \gamma_{i,2}]$ where the

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elements contain most energy, thus $\gamma_{i,1}{}^2 + \gamma_{i,2}{}^2 \geq \gamma_{j,1}{}^2 + \gamma_{j,2}{}^2$, $j = 1,2$. Then a solution is determined such that

$$\begin{pmatrix} \tilde{c}_1 \\ \tilde{c}_2 \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \end{pmatrix} - 3\mathbf{y} \text{ with } \mathbf{y} = \frac{\mathbf{B}(i,3)}{\max\left(\sum_{j=1,2} \gamma_{i,j}^2, \varepsilon^2\right)} \gamma^T .$$

If the obtained solution for $\tilde{c}_1$ and $\tilde{c}_2$ is outside the allowed range for prediction coefficients that is defined as $-2 \leq \tilde{c}_j \leq 3$ (as defined in ISO/IEC 23003-1:2007), $\tilde{c}_j$ shall be calculated according to the following.

First define the set of points, $\mathbf{x}_p$ as:

$$\mathbf{x}_p \in \begin{bmatrix} \begin{pmatrix} \min\left(3, \max\left(-2, -\frac{-2\gamma_{1,2} - b_1}{\gamma_{1,1} + \varepsilon}\right)\right) \\ -2 \end{pmatrix}, \begin{pmatrix} \min\left(3, \max\left(-2, -\frac{3\gamma_{1,2} - b_1}{\gamma_{1,1} + \varepsilon}\right)\right) \\ 3 \end{pmatrix} \\ \begin{pmatrix} -2 \\ \min\left(3, \max\left(-2, -\frac{-2\gamma_{2,1} - b_2}{\gamma_{2,2} + \varepsilon}\right)\right) \end{pmatrix}, \begin{pmatrix} 3 \\ \min\left(3, \max\left(-2, -\frac{3\gamma_{2,1} - b_2}{\gamma_{2,2} + \varepsilon}\right)\right) \end{pmatrix} \end{bmatrix},$$

and the distance function,

$$distFunc(\mathbf{x}_p) = \mathbf{x}_p^* \Gamma \mathbf{x}_{p1} - 2\mathbf{b}\mathbf{x}_p .$$

Then the prediction parameters are defined according to

$$\begin{pmatrix} \tilde{c}_1 \\ \tilde{c}_2 \end{pmatrix} = \arg\min_{\mathbf{x} \in \mathbf{x}_p} \left(distFunc(\mathbf{x}) \right).$$

The prediction parameters are constrained according to

$$c_1 = (1-\lambda)\tilde{c}_1 + \lambda\gamma_1, \quad c_2 = (1-\lambda)\tilde{c}_2 + \lambda\gamma_2 ,$$

where λ, γ_1 and γ_2 are defined as

$$\gamma_1 = \frac{2f_{1,1} + 2f_{5,5} - f_{3,3} + f_{1,3} + f_{5,3}}{2f_{1,1} + 2f_{5,5} + 2f_{3,3} + 4f_{1,3} + 4f_{5,3}}, \qquad \gamma_2 = \frac{2f_{2,2} + 2f_{6,6} - f_{3,3} + f_{2,3} + f_{6,3}}{2f_{2,2} + 2f_{6,6} + 2f_{3,3} + 4f_{2,3} + 4f_{6,3}},$$

$$\lambda = \left(\frac{\left(f_{1,2} + f_{1,6} + f_{5,2} + f_{5,6} + f_{1,3} + f_{5,3} + f_{2,3} + f_{6,3} + f_{3,3}\right)^2}{\left(f_{1,1} + f_{5,5} + f_{3,3} + 2f_{1,3} + 2f_{5,3}\right)\left(f_{2,2} + f_{6,6} + f_{3,3} + 2f_{2,3} + 2f_{6,3}\right)} \right)^8 .$$

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For the MPS decoder, the CPCs and corresponding ICC_{TTT} are provided as follows:

$$\mathbf{D}_{\text{CPC}}(h,l,m) = c_h, \qquad h = \{1,2\}, \text{ and}$$

$$\mathbf{D}_{\text{ICC}_{\text{TTT}}}(l,m) = 1.$$

Rendering between front and surround channels

The parameters that determine the rendering between front and surround channels can be estimated directly from the target covariance matrix **F** with

$$CLD_1 = 10\log_{10}\left(\frac{\max\left(f_{1,1},\varepsilon^2\right)}{\max\left(f_{5,5},\varepsilon^2\right)}\right), \qquad ICC_1 = \frac{\max\left(f_{1,5},\varepsilon^2\right)}{\sqrt{\max\left(f_{1,1},\varepsilon^2\right)\max\left(f_{5,5},\varepsilon^2\right)}},$$

$$CLD_2 = 10\log_{10}\left(\frac{\max\left(f_{2,2},\varepsilon^2\right)}{\max\left(f_{6,6},\varepsilon^2\right)}\right), \qquad ICC_2 = \frac{\max\left(f_{2,6},\varepsilon^2\right)}{\sqrt{\max\left(f_{2,2},\varepsilon^2\right)\max\left(f_{6,6},\varepsilon^2\right)}},$$

$$CLD_0 = 10\log_{10}\left(\frac{\max\left(f_{3,3},\varepsilon^2\right)}{\max\left(f_{4,4},\varepsilon^2\right)}\right).$$

The MPS parameters are provided in the form

$$\mathbf{D}_{\text{CLD}}(h,l,m) = CLD_h, \qquad \mathbf{D}_{\text{ICC}}(h,l,m) = ICC_h, \qquad h = \{0,1,2\}$$

for every OTT box *h*.

Dual mode

The SAOC transcoder can let the mix matrices $\mathbf{P}_1$, $\mathbf{P}_2$, and the prediction matrix $\mathbf{C}_3$ be calculated according to an alternative scheme for the upper frequency range. This alternative scheme is particularly useful for downmix signals where the upper frequency range is coded by a non-waveform preserving coding algorithm, e.g. SBR in High Efficiency AAC.

For the upper parameter bands, defined by **bsTttBandsLow** ≤ *pb* < *numBands*, $\mathbf{P}_1$, $\mathbf{P}_2$ and $\mathbf{C}_3$ should be calculated according to the alternative scheme described below:

$$\mathbf{P}_1 = \mathbf{P}_2 = \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}.$$

Define the energy downmix and energy target vectors, respectively:

$$\mathbf{e}_{\text{dmx}} = \begin{pmatrix} e_{\text{dmx1}} \\ e_{\text{dmx2}} \end{pmatrix} = diag\left(\mathbf{D}\mathbf{E}\mathbf{D}^*\right),$$

$$\mathbf{e}_{\text{tar}} = \begin{pmatrix} e_{\text{tar1}} \\ e_{\text{tar2}} \\ e_{\text{tar3}} \end{pmatrix} = diag\left(\mathbf{A}_3\mathbf{E}\mathbf{A}_3^*\right),$$

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and the help matrix

$$\mathbf{T} = \begin{pmatrix} t_{1,1} & t_{1,2} \\ t_{2,1} & t_{2,2} \\ t_{3,1} & t_{3,2} \end{pmatrix} = \mathbf{A}_3\mathbf{D}^*\mathbf{J}_\mathbf{D}\,.$$

The matrix $\mathbf{J}_\mathbf{D}$ is determined as $\mathbf{J_D} \approx \mathbf{\Delta}^{-1}$ according to 7.5.4 with $\mathbf{\Delta} = \mathbf{D}\mathbf{D}^*$.

The gain vector $\mathbf{g}$ is determined as

$$\mathbf{g} = \begin{pmatrix} g_1 \\ g_1 \\ g_1 \end{pmatrix} = \begin{pmatrix} \sqrt{\dfrac{e_{\text{tar1}}}{\max(t_{1,1}^2 e_{\text{dmx1}} + t_{1,2}^2 e_{\text{dmx2}}, \varepsilon^2)}} \\ \sqrt{\dfrac{e_{\text{tar2}}}{\max(t_{2,1}^2 e_{\text{dmx1}} + t_{2,2}^2 e_{\text{dmx2}}, \varepsilon^2)}} \\ \sqrt{\dfrac{e_{\text{tar3}}}{\max(t_{3,1}^2 e_{\text{dmx1}} + t_{3,2}^2 e_{\text{dmx2}}, \varepsilon^2)}} \end{pmatrix}.$$

The prediction matrix $\mathbf{C}_3$ is determined as

$$\mathbf{C}_3 = \begin{pmatrix} g_1 t_{1,1} & g_1 t_{1,2} \\ g_2 t_{2,1} & g_2 t_{2,2} \\ g_3 t_{3,1} & g_3 t_{3,2} \end{pmatrix}.$$

7.5.4 Computation of matrix J

The matrix $\mathbf{J} \approx \mathbf{\Delta}^{-1}$ of size 2×2 is defined as

$$\mathbf{J} = \begin{pmatrix} \mathbf{v}_1^J & \mathbf{v}_2^J \end{pmatrix} \begin{pmatrix} \hat{\lambda}_1^J & 0 \\ 0 & \hat{\lambda}_2^J \end{pmatrix} \begin{pmatrix} \mathbf{v}_1^J & \mathbf{v}_2^J \end{pmatrix}^*,$$

where both modified eigenvalues $\hat{\lambda}_i^J$ are determined as

$$\hat{\lambda}_i^J = \frac{1}{\max\left(\lambda_i^J, c^J\right)}, \qquad c^J = \frac{1}{80}.$$

The eigenvalues $\lambda_{1,2}^J$ ($\lambda_1^J \geq \lambda_2^J$) of the matrix $\mathbf{J}$ and corresponding eigenvectors $\mathbf{v}_{1,2}^J$ are calculated solving the following characteristic equations

$$\det\left(\mathbf{\Delta} - \lambda_{1,2}^J \mathbf{I}\right) = 0,$$

$$\left(\mathbf{\Delta} - \lambda_{1,2}^J \mathbf{I}\right)\mathbf{v}_{1,2}^J = 0\,.$$

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7.5.5 Decoding modes

7.5.5.1 General

In this subclause, the method for obtaining an output signal using SAOC parameters and panning information associated with each audio object is explained. The SAOC decoder is depicted in Figure 2 (right) and consists of the SAOC parameter processor and downmix processor.

The SAOC parameter processing unit calculates the upmix parameters ($\mathbf{G}$, $\mathbf{P}_1$, and $\mathbf{P}_2$) derived from the SAOC data (OLD, IOC, DMG, DCLD), rendering (and HRTF) information. The downmix processor applies these parameters and uses the corresponding synthesis filterbank yielding the final output PCM signal.

7.5.5.2 Mono to binaural "x-1-b" processing mode

The upmix parameters $\mathbf{G}$, $\mathbf{P}_1$ and $\mathbf{P}_2$ are computed as

$$\mathbf{G} = \begin{pmatrix} P_L \exp\left(j\frac{\phi_C}{2}\right)\cos(\beta+\alpha) & 0 \\ P_R \exp\left(-j\frac{\phi_C}{2}\right)\cos(\beta-\alpha) & 0 \end{pmatrix},$$

$$\mathbf{P}_1 = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix},$$

$$\mathbf{P}_2 = \begin{pmatrix} P_L \exp\left(j\frac{\phi_C}{2}\right)\sin(\beta+\alpha) & 0 \\ P_R \exp\left(-j\frac{\phi_C}{2}\right)\sin(\beta-\alpha) & 0 \end{pmatrix}$$

The gains P_L and P_R for the left and right output channels are defined as

$$P_L = \sqrt{\max\left(\frac{f_{1,1}}{v}, \varepsilon^2\right)} \text{ and } \qquad P_R = \sqrt{\max\left(\frac{f_{2,2}}{v}, \varepsilon^2\right)}.$$

The interchannel phase difference ϕ_C is given as

$$\phi_C = \begin{cases} \arg\left(f_{1,2}\right), & 0 \le m \le 11, \quad \rho_C \ge 0.6, \\ 0, & \text{otherwise.} \end{cases}$$

The interchannel coherence ρ_C is computed as

$$\rho_C = \min\left(\frac{\left|f_{1,2}\right|}{\sqrt{\max\left(f_{1,1}f_{2,2}, \varepsilon^2\right)}}, 1\right).$$

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The rotation angles α and β are given as

$$\alpha = \begin{cases} \frac{1}{2}\arccos\left(\rho_C \cos\left(\arg\left(f_{1,2}\right)\right)\right), & 0 \le m \le 11, \quad \rho_C < 0.6, \\ \frac{1}{2}\arccos\left(\rho_C\right), & \text{otherwise} \end{cases},$$

and

$$\beta = \arctan\left(\tan(\alpha)\frac{P_R - P_L}{P_L + P_R} \right).$$

7.5.5.3 Mono to stereo "x-1-2" processing mode

In case of stereo output, the "x-1-b" processing mode can be applied without using HRTF information. This can be done by deriving all elements $a_{i,j}$ of the rendering matrix $\mathbf{A}$, yielding:

$$a_{L,j} = m_{L,j}, \qquad a_{R,j} = m_{R,j}.$$

7.5.5.4 Mono to mono "x-1-1" processing mode

In case of mono output, the "x-1-2" processing mode can be applied with the following entries:

$$a_{L,j} = m_{C,j}, \qquad a_{R,j} = 0.$$

7.5.5.5 Stereo to binaural "x-2-b" processing mode

The upmix parameters $\mathbf{G}$, $\mathbf{P}_1$, and $\mathbf{P}_2$ are computed as

$$\mathbf{G} = \begin{pmatrix} P_L^0 \exp\left(j\frac{\phi^0}{2}\right)\cos(\beta+\alpha) & P_L^1 \exp\left(j\frac{\phi^1}{2}\right)\cos(\beta+\alpha) \\ P_R^0 \exp\left(-j\frac{\phi^0}{2}\right)\cos(\beta-\alpha) & P_R^1 \exp\left(-j\frac{\phi^1}{2}\right)\cos(\beta-\alpha) \end{pmatrix},$$

$$\mathbf{P}_1 = \begin{pmatrix} 1 & 1 \\ 0 & 0 \end{pmatrix},$$

$$\mathbf{P}_2 = \begin{pmatrix} P_L \exp\left(j\frac{\arg\left(c_{1,2}\right)}{2}\right)\sin(\beta+\alpha) & 0 \\ P_R \exp\left(-j\frac{\arg\left(c_{1,2}\right)}{2}\right)\sin(\beta-\alpha) & 0 \end{pmatrix}.$$

The corresponding gains P_L^x, P_R^x (with $x = 0,1$) and P_L, P_R for the left and right output channels are defined as

$$P_L^x = \sqrt{\max\left(\frac{f_{1,1}^x}{v^x}, \varepsilon^2\right)}, \qquad P_R^x = \sqrt{\max\left(\frac{f_{2,2}^x}{v^x}, \varepsilon^2\right)},$$

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$$P_L = \sqrt{\max\left(\frac{c_{1,1}}{v}, \varepsilon^2\right)}, \quad P_R = \sqrt{\max\left(\frac{c_{2,2}}{v}, \varepsilon^2\right)}.$$

The desired covariance matrix $\mathbf{F}^x$ of size 2×2 with elements $f_{i,j}^x$ is given as

$$\mathbf{F}^x = \mathbf{A}\mathbf{E}^x\mathbf{A}^*.$$

The covariance matrix $\mathbf{C}$ of size 2×2 with elements $c_{i,j}$ of the "dry" binaural signal is estimated as

$$\mathbf{C} = \widetilde{\mathbf{G}}\mathbf{D}\mathbf{E}\mathbf{D}^*\widetilde{\mathbf{G}}^*,$$

where

$$\widetilde{\mathbf{G}} = \begin{pmatrix} P_L^0 \exp\left(j\frac{\phi^0}{2}\right) & P_L^1 \exp\left(j\frac{\phi^1}{2}\right) \\ P_R^0 \exp\left(-j\frac{\phi^0}{2}\right) & P_R^1 \exp\left(-j\frac{\phi^1}{2}\right) \end{pmatrix}.$$

The corresponding scalars v^x and v are computed as

$$v^x = \mathbf{D}^x\mathbf{E}\left(\mathbf{D}^x\right)^* + \varepsilon^2,$$

$$v = \left(\mathbf{D}^0 + \mathbf{D}^1\right)\mathbf{E}\left(\mathbf{D}^0 + \mathbf{D}^1\right)^* + \varepsilon^2,$$

where the downmix matrix $\mathbf{D}^x$ of size $1 \times N$ contains the elements $d_{x,i}$, (with $x = 0,1$) of the downmix matrix $\mathbf{D}$ of size $2 \times N$.

The matrix $\mathbf{E}^x$ with elements $e_{i,j}^x$ (with $x = 0,1$) are derived from the following relationship

$$e_{i,j}^x = e_{i,j}\left(\frac{d_{x,i}}{d_{0,i} + d_{1,i}}\right)\left(\frac{d_{x,j}}{d_{0,j} + d_{1,j}}\right).$$

The interchannel phase differences ϕ^x are given as

$$\phi^x = \begin{cases} \arg\left(f_{1,2}^x\right), & 0 \le m \le 11, \quad \rho_C > 0.6, \\ 0, & \text{otherwise.} \end{cases}$$

The ICCs ρ_C and ρ_T are computed as

$$\rho_T = \min\left(\frac{|f_{1,2}|}{\sqrt{\max\left(f_{1,1}f_{2,2}, \varepsilon^2\right)}}, 1\right) \text{ and } \quad \rho_C = \min\left(\frac{|c_{1,2}|}{\sqrt{\max\left(c_{1,1}c_{2,2}, \varepsilon^2\right)}}, 1\right).$$

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The rotation angles α and β are given as

$$\alpha = \frac{1}{2}\left(\arccos\left(\rho_T\right) - \arccos\left(\rho_C\right)\right) \text{ and } \qquad \beta = \arctan\left(\tan(\alpha)\frac{P_R - P_L}{P_L + P_R}\right).$$

7.5.5.6 Stereo to stereo "x-2-2" processing mode

In case of stereo output, the stereo preprocessing is directly applied as described in 7.5.3.3.2.

7.5.5.7 Stereo to mono "x-2-1" processing mode

In case of mono output, the stereo preprocessing is applied with a single active rendering matrix entry as described in 7.5.3.3.2.

7.6 EAO processing for baseline and LD profiles

7.6.1 General

The SAOC technology allows the individual manipulation of a number of audio objects in terms of their level amplification/attenuation without significant decrease in the resulting sound quality only in a very limited way. A special "Karaoke-type" application scenario requires a total suppression of the specific objects, usually the lead vocal, keeping the perceptual quality of the background sound scene unharmed. A typical application case contains up to four enhanced audio object (EAO) signals, which can, for example, represent two independent stereo objects.

7.6.2 SAOC architecture supporting EAO

The EAO processing incorporates the OTN or TTN units, depending on the SAOC downmix mode. The OTN processing unit is dedicated to a mono and the TTN to a stereo downmix signal. Both these units represent a generalized and enhanced modification of the TTT box known from ISO/IEC 23003-1. In the encoder, regular and EAO signals are combined into the downmix. The OTN^{-1} /TTN^{-1} processing units are employed to produce and encode the corresponding residual signals. The EAO and regular signals are recovered from the downmix by the OTN/TTN units using the SAOC side information and incorporated residual signals. The recovered EAOs are fed into the rendering unit which represents the product of the corresponding rendering matrix and the resulting output of the OTN/TTN unit. The regular audio objects are delivered to the SAOC downmix pre-processor for further processing. Figure 16 depicts the general structure of the residual processor.

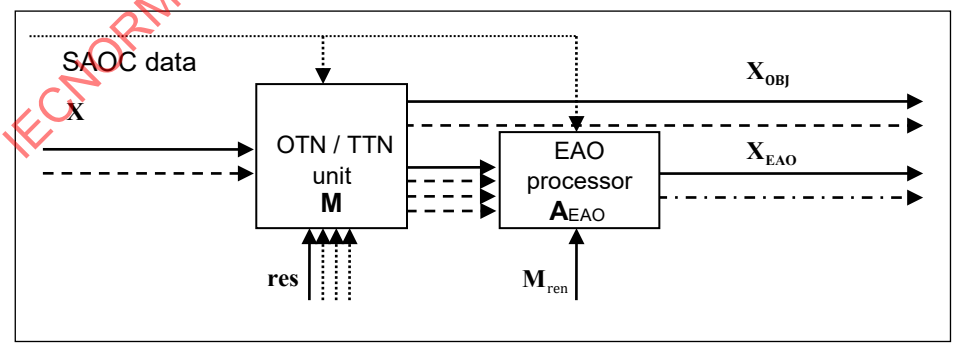

Figure 16 — Architecture of the residual processor

An MBO is treated the same way as explained in 7.10.

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The residual processor output signals is computed as

$$\mathbf{X}_{\mathrm{OBJ}} = \mathbf{M}_{\mathrm{OBJ}}\mathbf{X}_{\mathrm{res}}$$

and

$$\mathbf{X}_{\mathrm{EAO}} = \mathbf{A}_{\mathrm{EAO}}\mathbf{M}_{\mathrm{EAO}}\mathbf{X}_{\mathrm{res}},$$

where $\mathbf{X}_{\mathrm{OBJ}}$ represents the downmix signal of the regular audio objects (i.e. non-EAOs) and $\mathbf{X}_{\mathrm{EAO}}$ is the rendered EAO output signal for the SAOC decoding mode or the corresponding EAO downmix signal for the SAOC transcoding mode.

The residual processor can operate in prediction (using residual information) or energy (without residual information) mode. The extended input signal $\mathbf{X}_{\mathrm{res}}$ is defined as

$$\mathbf{X}_{\mathrm{res}} = \begin{pmatrix} \mathbf{X} \\ \hline \mathbf{res} \end{pmatrix}, \text{for prediction mode,}$$

$$\mathbf{X}_{\mathrm{res}} = \mathbf{X}, \quad \text{for energy mode.}$$

The OTN/TTN processing is represented by matrix $\mathbf{M}$ and EAO processor by matrix $\mathbf{A}_{\mathrm{EAO}}$. The OTN/TTN processing matrix $\mathbf{M}$ is defined according to the EAO operation mode (i.e. prediction or energy) as

$$\mathbf{M} = \mathbf{M}_{\mathrm{Prediction}}, \quad \text{for prediction mode,}$$

$$\mathbf{M} = \mathbf{M}_{\mathrm{Energy}}, \quad \text{for energy mode.}$$

The OTN/TTN processing matrix $\mathbf{M}$ is represented as

$$\mathbf{M} = \begin{pmatrix} \mathbf{M}_{\mathrm{OBJ}} \\ \mathbf{M}_{\mathrm{EAO}} \end{pmatrix},$$

where the matrix $\mathbf{M}_{\mathrm{OBJ}}$ relates to the regular audio objects (i.e. non-EAOs) and $\mathbf{M}_{\mathrm{EAO}}$ to the EAOs.

Calculation of the matrix $\mathbf{A}_{\mathrm{EAO}}$

The EAO pre-rendering matrix $\mathbf{A}_{\mathrm{EAO}}$ is defined according to the number of output channels (i.e. mono, stereo or binaural) as

$$\mathbf{A}_{\mathrm{EAO}} = \mathbf{A}_1^{\mathrm{EAO}}, \quad \text{for mono case,}$$

$$\mathbf{A}_{\mathrm{EAO}} = \mathbf{A}_2^{\mathrm{EAO}}, \quad \text{for other cases.}$$

The matrices $\mathbf{A}_1^{\mathrm{EAO}}$ of size $1 \times N_{\mathrm{EAO}}$ and $\mathbf{A}_2^{\mathrm{EAO}}$ of size $2 \times N_{\mathrm{EAO}}$ are defined as

$$\mathbf{A}_1^{\mathrm{EAO}} = \mathbf{D}_{16}^{\mathrm{EAO}}\mathbf{M}_{\mathrm{ren}}^{\mathrm{EAO}}, \quad \mathbf{D}_{16}^{\mathrm{EAO}} = \begin{pmatrix} w_1^{\mathrm{EAO}} & w_2^{\mathrm{EAO}} & w_3^{\mathrm{EAO}} & w_3^{\mathrm{EAO}} & w_1^{\mathrm{EAO}} & w_2^{\mathrm{EAO}} \end{pmatrix},$$

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$$\mathbf{A}_2^{\mathrm{EAO}} = \mathbf{D}_{26}^{\mathrm{EAO}} \mathbf{M}_{\mathrm{ren}}^{\mathrm{EAO}}, \quad \mathbf{D}_{26}^{\mathrm{EAO}} = \begin{pmatrix} w_1^{\mathrm{EAO}} & 0 & w_3^{\mathrm{EAO}} & w_3^{\mathrm{EAO}} & w_1^{\mathrm{EAO}} & 0 \\ 0 & w_2^{\mathrm{EAO}} & w_3^{\mathrm{EAO}} & w_3^{\mathrm{EAO}} & 0 & w_2^{\mathrm{EAO}} \end{pmatrix},$$

where the rendering sub-matrix $\mathbf{M}_{\mathrm{ren}}^{\mathrm{EAO}}$ corresponds to the EAO rendering.

The values w_i^{EAO} are computed as

$$w_1^{\mathrm{EAO}} = \sqrt{\frac{f_{1,1}^{\mathrm{EAO}} + f_{5,5}^{\mathrm{EAO}}}{\max\left(f_{1,1}^{\mathrm{EAO}} + f_{5,5}^{\mathrm{EAO}} + 2f_{1,5}^{\mathrm{EAO}}, \varepsilon^2\right)}}, \quad w_2^{\mathrm{EAO}} = \sqrt{\frac{f_{2,2}^{\mathrm{EAO}} + f_{6,6}^{\mathrm{EAO}}}{\max\left(f_{2,2}^{\mathrm{EAO}} + f_{6,6}^{\mathrm{EAO}} + 2f_{2,6}^{\mathrm{EAO}}, \varepsilon^2\right)}}, \quad w_3^{\mathrm{EAO}} = \frac{1}{\sqrt{2}},$$

where $f_{i,j}^{\mathrm{EAO}}$ denote the elements of $\mathbf{F}^{\mathrm{EAO}} = \mathbf{A}\mathbf{A}^*$. The matrix $\mathbf{A}$ is defined in 7.4.5.3.

In case of binaural rendering, the matrix $\mathbf{A}_2^{\mathrm{EAO}}$ is defined by formulae given in 7.7.2, for which the corresponding target binaural rendering matrix contains only EAO related elements.

7.6.3 Calculation of the OTN/TTN elements

7.6.3.1 General

The OTN/TTN upmix process is represented either by matrix $\mathbf{M}_{\mathrm{Prediction}}$ for the prediction mode or $\mathbf{M}_{\mathrm{Energy}}$ for the energy mode. In the first case, $\mathbf{M}_{\mathrm{Prediction}}$ is the product of two matrices exploiting the downmix information and the CPCs for each EAO channel. It is expressed in parameter-domain by

$$\mathbf{M}_{\mathrm{Prediction}} = \tilde{\mathbf{D}}^{-1}\mathbf{C},$$

where $\mathbf{C}$ contains the CPCs and $\tilde{\mathbf{D}}^{-1}$ is the inverse of the extended downmix matrix $\tilde{\mathbf{D}}$ of size 6×6 obtained with

$$\tilde{\mathbf{D}}^{-1} = \frac{\tilde{d}_{i,j}}{den}.$$

The elements $\tilde{d}_{i,j}$ are derived using the following formulae:

$$\tilde{d}_{1,1} = 1 + \sum_{j=1}^{4} n_j^2,$$

$$\tilde{d}_{1,2} = -\left(\sum_{j=1}^{4} m_j n_j\right),$$

$$\tilde{d}_{1,3} = m_1 + m_1 n_2^2 + m_1 n_3^2 + m_1 n_4^2 - m_2 n_1 n_2 - m_3 n_1 n_3 - m_4 n_1 n_4,$$

$$\tilde{d}_{1,4} = m_2 + m_2 n_1^2 + m_2 n_3^2 + m_2 n_4^2 - m_1 n_2 n_1 - m_3 n_2 n_3 - m_4 n_2 n_4,$$

$$\tilde{d}_{1,5} = m_3 + m_3 n_1^2 + m_3 n_2^2 + m_3 n_4^2 - m_1 n_3 n_1 - m_2 n_3 n_2 - m_4 n_3 n_4,$$

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$$\tilde{d}_{1,6} = m_4 + m_4 n_1^2 + m_4 n_2^2 + m_4 n_3^2 - m_1 n_4 n_1 - m_2 n_4 n_2 - m_3 n_4 n_3 ,$$

$$\tilde{d}_{2,2} = 1 + \sum_{j=1}^{4} m_j^2 ,$$

$$\tilde{d}_{2,3} = n_1 + n_1 m_2^2 + n_1 m_3^2 + n_1 m_4^2 - m_1 m_2 n_2 - m_1 m_3 n_3 - m_1 m_4 n_4 ,$$

$$\tilde{d}_{2,4} = n_2 + n_2 m_1^2 + n_2 m_3^2 + n_2 m_4^2 - m_2 m_1 n_1 - m_2 m_3 n_3 - m_2 m_4 n_4 ,$$

$$\tilde{d}_{2,5} = n_3 + n_3 m_1^2 + n_3 m_2^2 + n_3 m_4^2 - m_3 m_1 n_1 - m_3 m_2 n_2 - m_3 m_4 n_4 ,$$

$$\tilde{d}_{2,6} = n_4 + n_4 m_1^2 + n_4 m_2^2 + n_4 m_3^2 - m_4 m_1 n_1 - m_4 m_2 n_2 - m_4 m_3 n_3 ,$$

$$\tilde{d}_{3,3} = -1 - \sum_{j=2}^{4} m_j^2 - \sum_{j=2}^{4} n_j^2 - m_3^2 n_2^2 - m_4^2 n_2^2 - m_2^2 n_3^2 - m_4^2 n_3^2 - m_2^2 n_4^2 - m_3^2 n_4^2 + 2m_2 m_3 n_2 n_3 + 2m_2 m_4 n_2 n_4 + 2m_3 m_4 n_3 n_4 ,$$

$$\tilde{d}_{3,4} = m_1 m_2 + n_1 n_2 + m_3^2 n_1 n_2 + m_4^2 n_1 n_2 + m_1 m_2 n_3^2 + m_1 m_2 n_4^2 - m_2 m_3 n_1 n_3 - m_1 m_3 n_2 n_3 - m_2 m_4 n_1 n_4 - m_1 m_4 n_2 n_4 ,$$

$$\tilde{d}_{3,5} = m_1 m_3 + n_1 n_3 + m_2^2 n_1 n_3 + m_4^2 n_1 n_3 + m_1 m_3 n_2^2 + m_1 m_3 n_4^2 - m_2 m_3 n_1 n_2 - m_1 m_2 n_2 n_3 - m_3 m_4 n_1 n_4 - m_1 m_4 n_3 n_4 ,$$

$$\tilde{d}_{3,6} = m_1 m_4 + n_1 n_4 + m_2^2 n_1 n_4 + m_3^2 n_1 n_4 + m_1 m_4 n_2^2 + m_1 m_4 n_3^2 - m_2 m_4 n_1 n_2 - m_3 m_4 n_1 n_3 - m_1 m_2 n_2 n_4 - m_1 m_3 n_4 n_3 ,$$

$$\tilde{d}_{4,4} = -1 - \sum_{\substack{j=1 \\ j\neq 2}}^{4} m_j^2 - \sum_{\substack{j=1 \\ j\neq 2}}^{4} n_j^2 - m_3^2 n_1^2 - m_4^2 n_1^2 - m_1^2 n_3^2 - m_4^2 n_3^2 - m_1^2 n_4^2 - m_3^2 n_4^2 + 2m_1 m_3 n_1 n_3 + 2m_1 m_4 n_1 n_4 + 2m_3 m_4 n_3 n_4 ,$$

$$\tilde{d}_{4,5} = m_2 m_3 + n_2 n_3 + m_1^2 n_2 n_3 + m_4^2 n_2 n_3 + m_2 m_3 n_1^2 + m_2 m_3 n_4^2 - m_1 m_3 n_1 n_2 - m_1 m_2 n_1 n_3 - m_3 m_4 n_2 n_4 - m_2 m_4 n_3 n_4 ,$$

$$\tilde{d}_{4,6} = m_2 m_4 + n_2 n_4 + m_1^2 n_2 n_4 + m_3^2 n_2 n_4 + m_2 m_4 n_1^2 + m_2 m_4 n_3^2 - m_1 m_4 n_1 n_2 - m_3 m_4 n_2 n_3 - m_1 m_2 n_1 n_4 - m_2 m_3 n_3 n_4 ,$$

$$\tilde{d}_{5,5} = -1 - \sum_{\substack{j=1 \\ j\neq 3}}^{4} m_j^2 - \sum_{\substack{j=1 \\ j\neq 3}}^{4} n_j^2 - m_2^2 n_1^2 - m_4^2 n_1^2 - m_1^2 n_2^2 - m_4^2 n_2^2 - m_1^2 n_4^2 - m_2^2 n_4^2 + 2m_1 m_2 n_1 n_2 + 2m_1 m_4 n_1 n_4 + 2m_2 m_4 n_2 n_4 ,$$

$$\tilde{d}_{5,6} = m_3 m_4 + n_3 n_4 + m_1^2 n_3 n_4 + m_2^2 n_3 n_4 + m_3 m_4 n_1^2 + m_3 m_4 n_2^2 - m_1 m_4 n_1 n_3 - m_2 m_4 n_2 n_3 - m_1 m_3 n_1 n_4 - m_2 m_3 n_2 n_4 ,$$

$$\tilde{d}_{6,6} = -1 - \sum_{j=1}^{3} m_j^2 - \sum_{j=1}^{3} n_j^2 - m_2^2 n_1^2 - m_3^2 n_1^2 - m_1^2 n_2^2 - m_3^2 n_2^2 - m_1^2 n_3^2 - m_2^2 n_3^2 + 2m_1 m_2 n_1 n_2 + 2m_1 m_3 n_1 n_3 + 2m_2 m_3 n_2 n_3 ,$$

$$den = 1 + \sum_{j=1}^{4} m_j^2 + \sum_{j=1}^{4} n_j^2 + m_2^2 n_1^2 + m_3^2 n_1^2 + m_4^2 n_1^2 + m_1^2 n_2^2 + m_3^2 n_2^2 + m_4^2 n_2^2 + m_1^2 n_3^2 + m_2^2 n_3^2 + m_4^2 n_3^2 + m_1^2 n_4^2 + m_2^2 n_4^2 +$$
$$+ m_3^2 n_4^2 - 2m_1 m_2 n_1 n_2 - 2m_1 m_3 n_1 n_3 - 2m_2 m_3 n_2 n_3 - 2m_1 m_4 n_1 n_4 - 2m_2 m_4 n_2 n_4 - 2m_3 m_4 n_3 n_4 .$$

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The coefficients m_j and n_j of the extended downmix matrix $\widetilde{\mathbf{D}}$ denote the downmix values for every EAO j for the right and left downmix channel as

$$m_j = d_{0,\mathrm{EAO}(j)}, \quad n_j = d_{1,\mathrm{EAO}(j)}.$$

The elements $d_{i,j}$ of the downmix matrix **D** are obtained as described in 7.4.6.

The function $\mathrm{EAO}(j)$ determines mapping between indices of input audio object channels and EAO signals:

$$\mathrm{EAO}(j) = N - 1 - j, \qquad j = 0,\ldots,N_{\mathrm{EAO}} - 1.$$

The energy-based encoding/decoding procedure is designed for non-waveform preserving coding of the downmix signal. Thus, the OTN/TTN upmix matrix for the corresponding energy mode does not rely on specific waveforms, but only describe the relative energy distribution of the input audio objects.

7.6.3.2 TTN matrix using prediction mode

In case of a stereo output, the extended downmix matrix $\widetilde{\mathbf{D}}$ is

$$\widetilde{\mathbf{D}} = \left(\begin{array}{cc:ccc} 1 & 0 & m_0 & \cdots & m_{N_{\mathrm{EAO}}-1} \\ 0 & 1 & n_0 & \cdots & n_{N_{\mathrm{EAO}}-1} \\ \hdashline m_0 & n_0 & -1 & \cdots & 0 \\ \vdots & \vdots & 0 & \ddots & \vdots \\ m_{N_{\mathrm{EAO}}-1} & n_{N_{\mathrm{EAO}}-1} & 0 & \cdots & -1 \end{array}\right),$$

and for a mono output, it becomes

$$\widetilde{\mathbf{D}} = \left(\begin{array}{c:ccc} 1 & m_0 & \cdots & m_{N_{\mathrm{EAO}}-1} \\ 1 & n_0 & \cdots & n_{N_{\mathrm{EAO}}-1} \\ \hdashline m_0 + n_0 & -1 & \cdots & 0 \\ \vdots & 0 & \ddots & \vdots \\ m_{N_{\mathrm{EAO}}-1} + n_{N_{\mathrm{EAO}}-1} & 0 & \cdots & -1 \end{array}\right).$$

With a stereo downmix, each EAO j holds two CPCs $c_{j,0}$ and $c_{j,1}$ yielding matrix $\mathbf{C}$

$$\mathbf{C} = \left(\begin{array}{cc:ccc} 1 & 0 & 0 & \cdots & 0 \\ 0 & 1 & 0 & \cdots & 0 \\ \hdashline c_{0,0} & c_{0,1} & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ c_{N_{\mathrm{EAO}}-1,0} & c_{N_{\mathrm{EAO}}-1,1} & 0 & \cdots & 1 \end{array}\right).$$

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The CPCs are derived from the transmitted SAOC parameters, i.e. the OLDs, IOCs, DMGs and DCLDs. For one specific EAO channel $j = 0 \cdots N_{\mathrm{EAO}} - 1$ the CPCs can be estimated by

$$\tilde{c}_{j,0} = \frac{P_{LoCo,j} P_{Ro} - P_{RoCo,j} P_{LoRo}}{P_{Lo} P_{Ro} - P_{LoRo}^2}, \qquad \tilde{c}_{j,1} = \frac{P_{RoCo,j} P_{Lo} - P_{LoCo,j} P_{LoRo}}{P_{Lo} P_{Ro} - P_{LoRo}^2}.$$

The energy quantities P_{Lo}, P_{Ro}, P_{LoRo}, $P_{LoCo,j}$, and $P_{RoCo,j}$ are computed as

$$P_{Lo} = OLD_L + \sum_{j=0}^{N_{\mathrm{EAO}}-1} \sum_{k=0}^{N_{\mathrm{EAO}}-1} m_j m_k e_{j,k},$$

$$P_{Ro} = OLD_R + \sum_{j=0}^{N_{\mathrm{EAO}}-1} \sum_{k=0}^{N_{\mathrm{EAO}}-1} n_j n_k e_{j,k},$$

$$P_{LoRo} = e_{L,R} + \sum_{j=0}^{N_{\mathrm{EAO}}-1} \sum_{k=0}^{N_{\mathrm{EAO}}-1} m_j n_k e_{j,k},$$

$$P_{LoCo,j} = m_j OLD_L + n_j e_{L,R} - m_j OLD_j - \sum_{\substack{i=0 \\ i \neq j}}^{N_{\mathrm{EAO}}-1} m_i e_{i,j},$$

$$P_{RoCo,j} = n_j OLD_R + m_j e_{L,R} - n_j OLD_j - \sum_{\substack{i=0 \\ i \neq j}}^{N_{\mathrm{EAO}}-1} n_i e_{i,j}.$$

The parameters OLD_L, OLD_R, and IOC_{LR} correspond to the regular objects and can be derived using downmix information:

$$OLD_L = \sum_{i=0}^{N-N_{\mathrm{EAO}}-1} d_{0,i}^2 OLD_i$$

$$OLD_R = \sum_{i=0}^{N-N_{\mathrm{EAO}}-1} d_{1,i}^2 OLD_i$$

$$IOC_{L,R} = \begin{cases} IOC_{0,1}, & N - N_{\mathrm{EAO}} = 2, \\ 0, & \text{otherwise.} \end{cases}$$

The covariance matrix $e_{i,j}$ is defined in 7.4.3.2.

The CPCs are constrained by the subsequent limiting functions:

$$\gamma_{j,1} = \frac{m_j OLD_L + n_j e_{L,\mathrm{R}} - \sum_{i=0}^{N_{\mathrm{EAO}}-1} m_i e_{i,j}}{2\left(OLD_L + \sum_{i=0}^{N_{\mathrm{EAO}}-1} \sum_{k=0}^{N_{\mathrm{EAO}}-1} m_i m_k e_{i,k} \right)}, \qquad \gamma_{j,2} = \frac{n_j OLD_R + m_j e_{L,R} - \sum_{i=0}^{N_{\mathrm{EAO}}-1} n_i e_{i,j}}{2\left(OLD_R + \sum_{i=0}^{N_{\mathrm{EAO}}-1} \sum_{k=0}^{N_{\mathrm{EAO}}-1} n_i n_k e_{i,k} \right)},$$

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with the weighting factor

$$\lambda = \left(\frac{P_{LoRo}^2}{P_{Lo} P_{Ro}} \right)^8 .$$

The constrained CPCs become

$$c_{j,0} = (1-\lambda)\tilde{c}_{j,0} + \lambda\gamma_{j,0}, \qquad c_{j,1} = (1-\lambda)\tilde{c}_{j,1} + \lambda\gamma_{j,1}.$$

The residual processor output signals are computed as

$$\mathbf{X}_{\mathrm{OBJ}} = \mathbf{M}_{\mathrm{OBJ}}^{\mathrm{Prediction}} \begin{pmatrix} l_0 \\ r_0 \\ \hline res_0 \\ \cdots \\ res_{N_{\mathrm{EAO}}-1} \end{pmatrix},$$

$$\mathbf{X}_{\mathrm{EAO}} = \mathbf{A}_{\mathrm{EAO}} \mathbf{M}_{\mathrm{EAO}}^{\mathrm{Prediction}} \begin{pmatrix} l_0 \\ r_0 \\ \hline res_0 \\ \cdots \\ res_{N_{\mathrm{EAO}}-1} \end{pmatrix},$$

where $\begin{pmatrix} l_0 \\ r_0 \end{pmatrix}$ represents the input signal to the SAOC decoder/transcoder.

7.6.3.3 OTN matrix using prediction mode

In case of a stereo output, the extended downmix matrix $\tilde{\mathbf{D}}$ matrix is

$$\tilde{\mathbf{D}} = \left(\begin{array}{cc|ccc} 1 & 1 & m_0 & \cdots & m_{N_{\mathrm{EAO}}-1} \\ \hline m_0/2 & m_0/2 & -1 & \cdots & 0 \\ \vdots & \vdots & 0 & \ddots & \vdots \\ m_{N_{\mathrm{EAO}}-1}/2 & m_{N_{\mathrm{EAO}}-1}/2 & 0 & \cdots & -1 \end{array} \right),$$

and for a mono output, it becomes

$$\tilde{\mathbf{D}} = \left(\begin{array}{c|ccc} 1 & m_0 & \cdots & m_{N_{\mathrm{EAO}}-1} \\ \hline m_0 & -1 & \cdots & 0 \\ \vdots & 0 & \ddots & \vdots \\ m_{N_{\mathrm{EAO}}-1} & 0 & \cdots & -1 \end{array} \right).$$

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With a mono downmix, one EAO j is predicted by only one coefficient c_j yielding

$$\mathbf{C} = \left(\begin{array}{c|ccc} 1 & 0 & \cdots & 0 \\ \hline c_0 & 1 & \cdots & 0 \\ \vdots & 0 & \ddots & \vdots \\ c_{N_{\mathrm{EAO}}-1} & 0 & \cdots & 1 \end{array}\right).$$

All matrix elements c_j are obtained from the SAOC parameters according to the relationships provided in the previous subclause.

The residual processor output signals are computed as

$$\mathbf{X}_{\mathrm{OBJ}} = \mathbf{M}_{\mathrm{OBJ}}^{\mathrm{Prediction}} \left(\begin{array}{c} d_0 \\ \hline res_0 \\ \vdots \\ res_{N_{\mathrm{EAO}}-1} \end{array}\right),$$

$$\mathbf{X}_{\mathrm{EAO}} = \mathbf{A}_{\mathrm{EAO}} \mathbf{M}_{\mathrm{EAO}}^{\mathrm{Prediction}} \left(\begin{array}{c} d_0 \\ \hline res_0 \\ \vdots \\ res_{N_{\mathrm{EAO}}-1} \end{array}\right).$$

7.6.3.4 TTN matrix using energy mode

In case of a stereo output, the matrix $\mathbf{M}_{\mathrm{Energy}}$ are obtained from the corresponding OLDs according to

$$\mathbf{M}_{\mathrm{Energy}} = \mathbf{A} \left(\begin{array}{cc} \sqrt{\frac{OLD_L}{OLD_L + \sum_{i=0}^{N_{\mathrm{EAO}}-1} m_i^2 OLD_i}} & 0 \\ 0 & \sqrt{\frac{OLD_R}{OLD_R + \sum_{i=0}^{N_{\mathrm{EAO}}-1} n_i^2 OLD_i}} \\ \hline \sqrt{\frac{m_0^2 OLD_0}{OLD_L + \sum_{i=0}^{N_{\mathrm{EAO}}-1} m_i^2 OLD_i}} & \sqrt{\frac{n_0^2 OLD_0}{OLD_R + \sum_{i=0}^{N_{\mathrm{EAO}}-1} n_i^2 OLD_i}} \\ \vdots & \vdots \\ \sqrt{\frac{m_{N_{\mathrm{EAO}}-1}^2 OLD_{N_{\mathrm{EAO}}-1}}{OLD_L + \sum_{i=0}^{N_{\mathrm{EAO}}-1} m_i^2 OLD_i}} & \sqrt{\frac{n_{N_{\mathrm{EAO}}-1}^2 OLD_{N_{\mathrm{EAO}}-1}}{OLD_R + \sum_{i=0}^{N_{\mathrm{EAO}}-1} n_i^2 OLD_i}} \end{array}\right).$$

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The residual processor output signals are computed as

$$\mathbf{X}_{\text{OBJ}} = \mathbf{M}_{\text{OBJ}}^{\text{Energy}} \begin{pmatrix} l_0 \\ r_0 \end{pmatrix},$$

$$\mathbf{X}_{\text{EAO}} = \mathbf{A}_{\text{EAO}} \mathbf{M}_{\text{EAO}}^{\text{Energy}} \begin{pmatrix} l_0 \\ r_0 \end{pmatrix}.$$

The adaptation of the formulae for the mono signal results in

$$\mathbf{M}_{\text{Energy}} = \mathbf{A} \begin{pmatrix} \sqrt{\frac{OLD_L}{OLD_L + \sum_{i=0}^{N_{\text{EAO}}-1} m_i^2 OLD_i}} & \sqrt{\frac{OLD_L}{OLD_L + \sum_{i=0}^{N_{\text{EAO}}-1} n_i^2 OLD_i}} \\ \sqrt{\frac{m_0^2 OLD_0}{OLD_L + \sum_{i=0}^{N_{\text{EAO}}-1} m_i^2 OLD_i}} & \sqrt{\frac{n_0^2 OLD_0}{OLD_L + \sum_{i=0}^{N_{\text{EAO}}-1} n_i^2 OLD_i}} \\ \vdots & \vdots \\ \sqrt{\frac{m_{N_{\text{EAO}}-1}^2 OLD_{N_{\text{EAO}}-1}}{OLD_L + \sum_{i=0}^{N_{\text{EAO}}-1} m_i^2 OLD_i}} & \sqrt{\frac{n_{N_{\text{EAO}}-1}^2 OLD_{N_{\text{EAO}}-1}}{OLD_L + \sum_{i=0}^{N_{\text{EAO}}-1} n_i^2 OLD_i}} \end{pmatrix}.$$

The residual processor output signals are computed as

$$\mathbf{X}_{\text{OBJ}} = \mathbf{M}_{\text{OBJ}}^{\text{Energy}} \left(d_0 \right),$$

$$\mathbf{X}_{\text{EAO}} = \mathbf{A}_{\text{EAO}} \mathbf{M}_{\text{EAO}}^{\text{Energy}} \left(d_0 \right).$$

7.6.3.5 OTN matrix using energy mode

The corresponding OTN matrix $\mathbf{M}_{\text{Energy}}$ for the stereo output case can be derived as

$$\mathbf{M}_{\text{Energy}} = \mathbf{A} \left(\frac{1}{\sqrt{OLD_L + \sum_{i=0}^{N_{\text{EAO}}-1} m_i^2 OLD_i}} + \frac{1}{\sqrt{OLD_R + \sum_{i=0}^{N_{\text{EAO}}-1} n_i^2 OLD_i}} \right) \begin{pmatrix} \sqrt{OLD_L} \\ \sqrt{OLD_R} \\ \hline \sqrt{m_0^2 OLD_0} + \sqrt{n_0^2 OLD_0} \\ \vdots \\ \sqrt{m_{N_{\text{EAO}}-1}^2 OLD_{N_{\text{EAO}}-1}} + \sqrt{n_{N_{\text{EAO}}-1}^2 OLD_{N_{\text{EAO}}-1}} \end{pmatrix}$$

Hence, the output signal $\mathbf{Y}$ of the OTN element yields

$$\mathbf{Y} = \mathbf{M}_{\text{Energy}} \mathbf{d}_0 .$$

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For the mono output case the OTN matrix $\mathbf{M}_{\text{Energy}}$ reduces to

$$\mathbf{M}_{\text{Energy}} = \mathbf{A}\frac{1}{\sqrt{OLD_L + \sum_{i=0}^{N_{\text{EAO}}-1} m_i^2 OLD_i}}\begin{pmatrix} \sqrt{OLD_L} \\ \sqrt{m_0^2 OLD_0} \\ \vdots \\ \sqrt{m_{N_{\text{EAO}}-1}^2 OLD_{N_{\text{EAO}}-1}} \end{pmatrix}.$$

Renormalization of OLD parameters

For the SAOC parameter processor the OLD parameters of the regular audio objects are renormalized as follows:

$$OLD_i^{\text{Ren}} = \frac{OLD_i^{\text{X}_{\text{obj}}}}{\max\left(OLD_i^{\text{X}_{\text{obj}}}\right)},$$

where $OLD_i^{\text{X}_{\text{obj}}}$ represents a subset of OLD parameters corresponding to the signals remaining in the downmix after application of the residual processor.

7.7 SAOC-DE profile decoding modes

7.7.1 Overview

The general structure of the SAOC-DE decoding modes consist of two signal paths (see Figure 17).

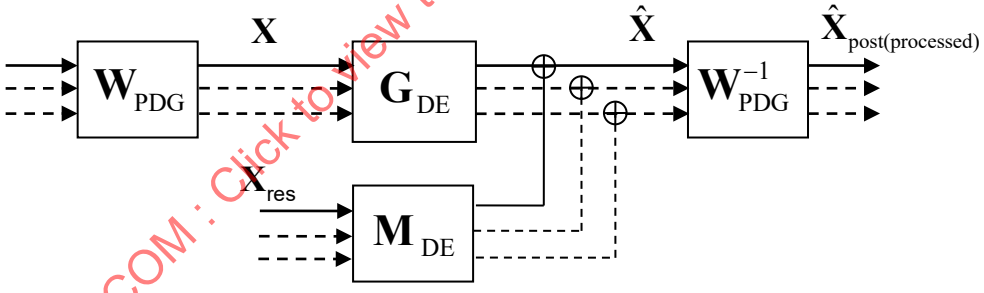

Figure 17 — Basic structure for SAOC-DE profile decoding modes

The output signal of the SAOC decoder is produced by the corresponding mixing of a modified downmix signal and a processed residual signal as follows:

$$\hat{\mathbf{X}} = \mathbf{G}_{\text{DE}}\mathbf{X} + \mathbf{M}_{\text{DE}}\mathbf{X}_{\text{res}}.$$

7.7.2 SAOC-DE parametric processing mode

7.7.2.1 General

The upmix matrix $\mathbf{G}_{\text{DE}}$ is computed as

$$\mathbf{G}_{\text{DE}} = \mathbf{M}_{\text{ren}}\mathbf{E}\mathbf{D}^{*}\mathbf{J}_{\text{DE}}.$$

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The residual signal path is disabled by

$$\mathbf{M}_{\mathrm{DE}} = \mathbf{0}_{\mathrm{M\times M}}.$$

The matrix $\mathbf{J}_{\mathrm{DE}} \approx \left(\mathbf{DED}^{*}\right)^{-1}$ of size $M \times M$ is defined as

$$\mathbf{J}_{\mathrm{DE}} = \mathbf{U}\Delta^{inv}\mathbf{U}^{*}.$$

Here, the singular vector $\mathbf{U}$ of the matrix product $\mathbf{\Delta} = \mathbf{DED}^{*}$ is obtained using the following characteristic formula

$$\mathbf{U\Lambda U}^{*} = \mathbf{\Delta}.$$

The regularized inverse, $\mathbf{\Lambda}^{inv}$, of the diagonal singular value matrix $\mathbf{\Lambda}$ is computed as described in the following.

A number N_{g} of sub-matrices $\mathbf{\Delta}_{\mathrm{q}}$ (of size $N_{\mathrm{g}}^{q} \times N_{\mathrm{g}}^{q}$) is determined as described in 7.7.2.2. For each sub-matrix $\mathbf{\Delta}_{\mathrm{q}}$, the regularized inverse $\mathrm{J}_{\mathrm{q}} \approx \Delta_{\mathrm{q}}^{-1}$ is determined as described in 7.7.2.3.

The results of the independent regularized inversion operations $\mathrm{J}_{\mathrm{q}} \approx \Delta_{\mathrm{q}}^{-1}$ are combined for obtaining the matrix $\mathbf{J}_{\mathrm{DE}}$ as:

$$\mathbf{J}_{\mathrm{DE}}\left(ch_1, ch_2\right) = \begin{cases} \mathbf{J}_{\mathrm{q}}\left(idx_1, idx_2\right), & \mathbf{g}_{q}\left(idx_1\right) = ch_1 \text{ and } \mathbf{g}_{q}\left(idx_2\right) = ch_2, \\ 0, & \text{otherwise,} \end{cases}$$

where $\mathbf{g}_{\mathrm{q}}$ is specified in 7.7.2.2.

7.7.2.2 Grouping of downmix channels

A sub-matrix $\mathbf{\Delta}_{\mathrm{q}}$ of size $N_{\mathrm{g}}^{q} \times N_{\mathrm{g}}^{q}$, with elements $\mathbf{\Delta}_{\mathrm{q}}\left(idx_1, idx_2\right)$, is obtained by selecting the elements $\mathbf{\Delta}\left(ch_1, ch_2\right)$ corresponding to the downmix channels ch_1 and ch_2 assigned to the group $\mathbf{g}_q$ (i.e. $\mathbf{g}_{q}\left(idx_1\right) = ch_1$ and $\mathbf{g}_{q}\left(idx_2\right) = ch_2$).

The group $\mathbf{g}_q$ of size $1 \times N_{\mathrm{g}}^{q}$ is defined by the smallest set of downmix channels with the following properties.

— The input signals contained in the downmix channels of group $\mathbf{g}_q$ are not contained in any other downmix channel. An input signal is not contained in a downmix channel if the corresponding downmix gain is given by the smallest quantization index (see Table 53).

— All input signals i contained in the downmix channels of group $\mathbf{g}_q$ are not related to any input signal j contained in any downmix channel of any other group (i.e. **bsRelatedTo**[i][j] == 0).

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7.7.2.3 Regularization of singular values

The regularized inverse operation $(\cdot)^{inv}$ used for the diagonal singular value matrix $\mathbf{\Lambda}$ is determined as

$$\mathbf{\Lambda}^{inv} = \lambda_{i,j}^{inv} = \begin{cases} \dfrac{1}{\lambda_{i,i}} & \text{, if } i = j \text{ and } abs\left(\lambda_{i,i}\right) \geq T_{\text{reg}}^{\Lambda}, \\ 0 & \text{, otherwise.} \end{cases}$$

The relative regularization scalar T_{reg}^{Λ} is determined using absolute threshold T_{reg} and maximal value of $\mathbf{\Lambda}$ as

$$T_{\text{reg}}^{\Lambda} = \max\left(abs\left(\lambda_{i,i}\right)\right) T_{\text{reg}}, \quad T_{\text{reg}} = 10^{-2}.$$

7.7.3 SAOC-DE EAO processing mode

The final output $\hat{\mathbf{X}}$ of the SAOC decoder is defined from the downmix signal $\mathbf{X}$ using the SAOC parametric information, residual signal $\mathbf{X}_{\text{res}}$, and rendering control variables m_{BGO}, m_{FGO} as

$$\hat{\mathbf{X}} = m_{\text{BGO}}\mathbf{X} + (m_{\text{FGO}} - m_{\text{BGO}})\mathbf{D}_{\text{FGO}}\left(\mathbf{R}_{\text{eao}}\mathbf{E}\mathbf{D}^{*}\mathbf{J}_{\text{DE}}\mathbf{X} + \mathbf{X}_{\text{res}}\right),$$

where matrix $\mathbf{J}_{\text{DE}}$ is computed in 7.7.2.

This formula can be represented also in the following form

$$\hat{\mathbf{X}} = \mathbf{G}_{\text{DE}}\mathbf{X} + \mathbf{M}_{\text{DE}}\mathbf{X}_{\text{res}},$$

where

$$\mathbf{G}_{\text{DE}} = m_{\text{BGO}}\mathbf{I}_{M} + (m_{\text{FGO}} - m_{\text{BGO}})\mathbf{D}_{\text{FGO}}\mathbf{R}_{\text{eao}}\mathbf{E}\mathbf{D}^{*}\mathbf{J}_{\text{DE}},$$

$$\mathbf{M}_{\text{DE}} = (m_{\text{FGO}} - m_{\text{BGO}})\mathbf{D}_{\text{FGO}}.$$

The term $\mathbf{X}_{\text{res}}$ of size N_{EAO} incorporates residual signals **res** for EAOs from SAOC bitstream:

$$\mathbf{X}_{\text{res}} = \mathbf{res}.$$

The matrix $\mathbf{R}_{\text{eao}}$ is defined as $\mathbf{R}_{\text{eao}} = \left(\mathbf{0}_{N_{\text{EAO}} \times N - N_{\text{EAO}}} \quad \mathbf{I}_{N_{\text{EAO}}}\right)$.

7.8 DCU processing

7.8.1 General

Within the overall SAOC system, the distortion control unit (DCU) is incorporated into the SAOC decoder/transcoder processing chain between the rendering interface and the actual SAOC decoding/transcoding unit. It provides a modified rendering matrix using the information from the rendering interface and SAOC data (see Figure 18). The modified rendering matrix can be accessed by the application, reflecting the actually effective rendering settings.

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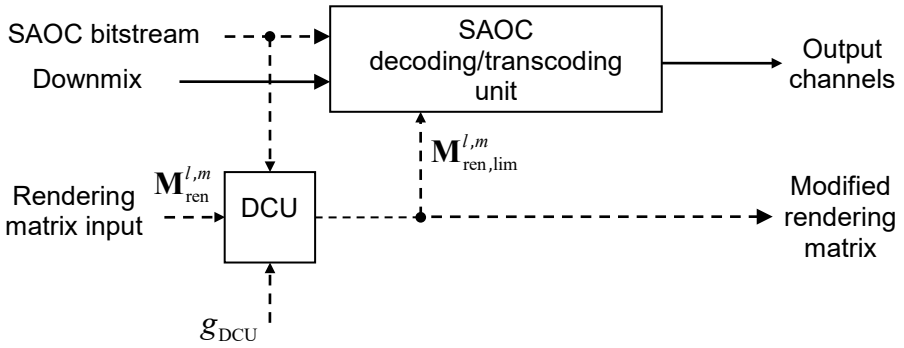

Figure 18 — DCU within the overall SAOC system

Based on the user specified rendering scenario represented by rendering matrix $\mathbf{M}^{l,m}_{\text{ren}}$ with elements $m^{l,m}_{i,j}$, the DCU prevents extreme rendering settings by producing a modified matrix $\mathbf{M}^{l,m}_{\text{ren,lim}}$ comprising limited rendering coefficients, which shall be used by the SAOC rendering engine. For all operational modes of SAOC, the final (DCU processed) rendering coefficients shall be calculated according to

$$\mathbf{M}^{l,m}_{\text{ren,lim}} = \left(1 - g_{\text{DCU}}\right)\mathbf{M}^{l,m}_{\text{ren}} + g_{\text{DCU}}\mathbf{M}^{l,m}_{\text{ren,tar}}\,.$$

The parameter $g_{\text{DCU}} \in [0,1]$ is used to define the degree of transition from the user specified rendering matrix $\mathbf{M}^{l,m}_{\text{ren}}$ towards the distortion-free target matrix $\mathbf{M}^{l,m}_{\text{ren,tar}}$. The parameter g_{DCU} is derived from the bitstream element **bsDcuParam** according to:

g_{DCU} = DcuParam[**bsDcuParam**].

The parameter g_{DCU} can be also set by the user or application.

There are two possible versions of the distortion-free target matrix $\mathbf{M}^{l,m}_{\text{ren,tar}}$, suited for different applications. It is controlled by the bitstream element **bsDcuMode**:

— (**bsDcuMode** == 0): the "downmix-similar" rendering, where $\mathbf{M}^{l,m}_{\text{ren,tar}}$ corresponds to the energy normalized downmix matrix;

— (**bsDcuMode** == 1): the "best effort" rendering, where $\mathbf{M}^{l,m}_{\text{ren,tar}}$ is defined as a function of both downmix and target rendering matrix.

7.8.2 DCU application for EAO

For SAOC decoders that decode residual coding data and thus support the handling of EAOs, it can be meaningful to provide a second parameterization of the DCU which allows to take advantage of the enhanced audio quality provided by the use of EAOs. This is achieved by decoding and using a second alternate set of DCU parameters (i.e. **bsDcuMode2** and **bsDcuParam2**) which is transmitted as part of the data structures containing residual data (i.e. SAOCExtensionConfigData() and SAOCExtensionFrameData()). An application can make use of this second parameter set if it decodes residual coding data and operates in strict EAO mode which is defined by the condition that only EAOs can be modified arbitrarily while all non-EAOs only undergo a single common modification. Specifically, this strict EAO mode requires fulfillment of two following conditions.

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— The downmix matrix and rendering matrix have the same dimensions (implying that the number of rendering channels is equal to the number of downmix channels).

— The application only employs rendering coefficients for each of the regular objects (i.e. non-EAOs) that are related to their corresponding downmix coefficients by a single common scaling factor.

7.8.3 "Downmix-similar" rendering

7.8.3.1 General

The "downmix-similar" rendering method can typically be used in cases where the downmix is an important reference of artistic high quality.

The "downmix-similar" rendering matrix $\mathbf{M}_{\text{ren,DS}}^{l,m}$ is computed as

$$\mathbf{M}_{\text{ren,DS}}^{l,m} = \mathbf{M}_{\text{ren,tar}}^{l,m} = \sqrt{N_{\text{DS}}^{l,m}}\,\mathbf{D}_{\text{DS}}^{l},$$

where $N_{\text{DS}}^{l,m}$ represents the energy normalization scalar (for each parameter time slot l and processing band m) and $\mathbf{D}_{\text{DS}}^{l}$ is the downmix matrix extended by rows of zero elements such that number and order of the rows of $\mathbf{D}_{\text{DS}}^{l}$ correspond to the constellation of $\mathbf{M}_{\text{ren}}^{l,m}$ (of processing band m). For example, in the SAOC stereo to multichannel transcoding mode ("x-2-5" processing mode), the number of output channels is $N_{\text{MPS}} = 6$. Accordingly, $\mathbf{D}_{\text{DS}}^{l}$ is of size $N_{\text{MPS}} \times N$ and its rows representing the front left and right output channels equal $\mathbf{D}^{l}$.

Note that the extended downmix matrix $\mathbf{D}_{\text{DS}}^{l}$ is independent from the frequency parameter m since the downmix matrix $\mathbf{D}^{l}$ is frequency invariant.

7.8.3.2 All decoding/transcoding SAOC modes

For all decoding/transcoding SAOC modes the energy normalization scalar $N_{\text{DS}}^{l,m}$ is computed using the following formula:

$$N_{\text{DS}}^{l,m} = \frac{trace\left(\mathbf{M}_{\text{ren}}^{l,m}\left(\mathbf{M}_{\text{ren}}^{l,m}\right)^{*}\right) + \varepsilon^{2}}{trace\left(\mathbf{D}^{l}\left(\mathbf{D}^{l}\right)^{*}\right) + \varepsilon^{2}}.$$

7.8.4 "Best effort" rendering

7.8.4.1 General

The "best effort" rendering method can typically be used in cases where the target rendering is an important reference.

The "best effort" rendering matrix describes a target rendering matrix, which depends on the downmix and rendering information. The energy normalization is represented by a matrix $\mathbf{N}_{\text{BE}}^{l,m}$ of size $N_{\text{MPS}} \times M$, hence it provides individual values for each downmix-to-output channel transformation. This requires different calculations of $\mathbf{N}_{\text{BE}}^{l,m}$ for the different SAOC operation modes, which are outlined in the following. The "best effort" rendering matrix is computed as

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$$\mathbf{M}_{\text{ren,BE}} = \mathbf{M}_{\text{ren,tar}} = \sqrt{\mathbf{N}_{\text{BE}}}\mathbf{D} \ , \qquad \text{for all mono downmix modes “x-1-1/2/5/b”,}$$

$$\mathbf{M}_{\text{ren,BE}} = \mathbf{M}_{\text{ren,tar}} = \mathbf{N}_{\text{BE}}\mathbf{D} \ , \qquad \text{for all stereo downmix modes “x-2-1/2/5/b”,}$$

where $\mathbf{D}^l$ is the downmix matrix and $\mathbf{N}_{\text{BE}}^{l,m}$ represents the energy normalization matrix.

7.8.4.2 SAOC mono-to-mono (“x-1-1”) decoding mode

For the “x-1-1” SAOC mode, the energy normalization scalar $\mathbf{N}_{\text{BE}}^{l,m}$ is computed using the following formula:

$$\mathbf{N}_{\text{BE}}^{l,m} = \frac{\sum_{j=0}^{N-1}\left(m_{C,j}^{l,m}\right)^2 + \varepsilon^2}{\sum_{j=0}^{N-1}\left(d_j^l\right)^2 + \varepsilon^2}.$$

7.8.4.3 SAOC mono-to-stereo (“x-1-2”) decoding mode

For the “x-1-2” SAOC mode, the energy normalization matrix $\mathbf{N}_{\text{BE}}^{l,m}$ of size 2×1 is computed using the following formula:

$$\mathbf{N}_{\text{BE}}^{l,m} = \left(\frac{\sum_{j=0}^{N-1}\left(m_{L,j}^{l,m}\right)^2 + \varepsilon^2}{\sum_{j=0}^{N-1}\left(d_j^l\right)^2 + \varepsilon^2}, \ \frac{\sum_{j=0}^{N-1}\left(m_{R,j}^{l,m}\right)^2 + \varepsilon^2}{\sum_{j=0}^{N-1}\left(d_j^l\right)^2 + \varepsilon^2} \right)^T.$$

7.8.4.4 SAOC mono-to-binaural (“x-1-b”) decoding mode

For the “x-1-b” SAOC mode, the energy normalization matrix $\mathbf{N}_{\text{BE}}^{l,m}$ of size 2×1 is computed using the following formula:

$$\mathbf{N}_{\text{BE}}^{l,m} = \left(\frac{\sum_{j=0}^{N-1} a_{L,j}^{l,m}\left(a_{L,j}^{l,m}\right)^* + \varepsilon^2}{\sum_{j=0}^{N-1}\left(d_j^l\right)^2 + \varepsilon^2}, \ \frac{\sum_{j=0}^{N-1} a_{R,j}^{l,m}\left(a_{R,j}^{l,m}\right)^* + \varepsilon^2}{\sum_{j=0}^{N-1}\left(d_j^l\right)^2 + \varepsilon^2} \right)^T.$$

The elements $a_{L,j}^{l,m}$ and $a_{R,j}^{l,m}$ comprise the target binaural rendering matrix $\mathbf{A}^{l,m}$.

7.8.4.5 SAOC stereo-to-mono (“x-2-1”) decoding mode

For the “x-2-1” SAOC mode, the energy normalization matrix $\mathbf{N}_{\text{BE}}^{l,m}$ of size 1×2 is computed using the following formula:

$$\mathbf{N}_{\text{BE}}^{l,m} = \mathbf{M}_{\text{ren}}^{l,m}\left(\mathbf{D}^l\right)^*\mathbf{J}^l,$$

where $\mathbf{M}_{\text{ren}}^{l,m}$ is mono rendering matrix of size $1\times N$.

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7.8.4.6 SAOC stereo-to-stereo ("x-2-2") decoding mode

For the "x-2-2" SAOC mode, the energy normalization matrix $\mathbf{N}_{\mathrm{BE}}^{l,m}$ of size 2×2 is computed using the following formula:

$$\mathbf{N}_{\mathrm{BE}}^{l,m} = \mathbf{M}_{\mathrm{ren}}^{l,m}\left(\mathbf{D}^{l}\right)^{*}\mathbf{J}^{l},$$

where $\mathbf{M}_{\mathrm{ren}}^{l,m}$ is stereo rendering matrix of size $2\times N$.

7.8.4.7 SAOC stereo-to-binaural ("x-2-b") decoding mode

For the "x-2-b" SAOC mode, the energy normalization matrix $\mathbf{N}_{\mathrm{BE}}^{l,m}$ of size 2×2 is computed using the following formula:

$$\mathbf{N}_{\mathrm{BE}}^{l,m} = \mathbf{M}_{\mathrm{ren}}^{l,m}\left(\mathbf{D}^{l}\right)^{*}\mathbf{J}^{l},$$

where $\mathbf{A}^{l,m}$ is binaural rendering matrix of size $2\times N$.

7.8.4.8 SAOC mono-to-multichannel ("x-1-5") transcoding mode

For the "x-1-5" SAOC mode, the energy normalization matrix $\mathbf{N}_{\mathrm{BE}}^{l,m}$ of size $N_{\mathrm{MPS}}\times 1$ is computed using the following formula:

$$\mathbf{N}_{\mathrm{BE}}^{l,m} = \left(\frac{\sum_{j=0}^{N-1}\left(m_{0,j}^{l,m}\right)^{2}+\varepsilon^{2}}{\sum_{j=0}^{N-1}\left(d_{j}^{l}\right)^{2}+\varepsilon^{2}},\ \vdots,\ \frac{\sum_{j=0}^{N-1}\left(m_{N_{\mathrm{MPS}}-1,j}^{l,m}\right)^{2}+\varepsilon^{2}}{\sum_{j=0}^{N-1}\left(d_{j}^{l}\right)^{2}+\varepsilon^{2}}\right)^{T}.$$

7.8.4.9 SAOC stereo-to-multichannel ("x-2-5") transcoding mode

For the "x-2-5" SAOC mode, the energy normalization matrix $\mathbf{N}_{\mathrm{BE}}^{l,m}$ of size $N_{\mathrm{MPS}}\times 2$ is computed using the following formula:

$$\mathbf{N}_{\mathrm{BE}} = \mathbf{M}_{\mathrm{ren}}\mathbf{D}^{*}\mathbf{J}_{\mathbf{D}}.$$

The matrix $\mathbf{J}_{\mathbf{D}}$ is determined as $\mathbf{J}_{\mathbf{D}} \approx \mathbf{\Delta}^{-1}$ according to 7.5.4 with $\mathbf{\Delta} = \mathbf{D}\mathbf{D}^{*}$.

7.9 Modification range control for SAOC-DE processing modes

The modification scalar, m_{G}, is obtained from decoder input parameter, m_{G}^{input}, using the limitation thresholds $m_{\mathrm{DeLimitFgo}}$ and $m_{\mathrm{DeLimitBgo}}$ for BGO and FGO as

$$m_{\mathrm{G}} = \begin{cases} \max\left(m_{\mathrm{G}}^{input}, m_{\mathrm{DeLimitFgo}}\right), & m_{\mathrm{G}}^{input} \le 1, \\ \min\left(m_{\mathrm{G}}^{input}, m_{\mathrm{DeLimitBgo}}^{-1}\right), & m_{\mathrm{G}}^{input} > 1. \end{cases}$$

Here, values of the limitation thresholds $m_{\mathrm{DeLimitFgo}} \in (0,1]$ and $m_{\mathrm{DeLimitBgo}} \in (0,1]$ are obtained from bitstream variables **bsDeLimitFgo**, **bsDeLimitFgoEAO**, **bsDeLimitBgo** and **bsDeLimitBgoEAO** as

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$m_{\text{DeLimitFgo}} = \text{DeLimit}[\textbf{bsDeLimitFgo}]$, for FGO in non-EAO mode,

$m_{\text{DeLimitBgo}} = \text{DeLimit}[\textbf{bsDeLimitBgo}]$, for BGO in non-EAO mode,

$m_{\text{DeLimitFgo}} = \text{DeLimit}[\textbf{bsDeLimitFgoEAO}]$, for FGO in EAO mode,

$m_{\text{DeLimitBgo}} = \text{DeLimit}[\textbf{bsDeLimitBgoEAO}]$, for BGO in EAO mode.

The decoder input parameter is non-negative $m_{\text{G}}^{input} \geq 0$ and has the default value $m_{\text{G}}^{input} = 1$ which disables the BGO/FGO modification functionality by making the rendering matrix equal to the downmixing matrix $\mathbf{M}_{\text{ren}} = \mathbf{D}$.

Output interface for the decoder limited modification gain

For an efficient practical implementation of additional external functionalities like level adjustment of bypassed (unprocessed by SAOC) channels, comprising multichannel audio scene (e.g. for 5.1 playback systems), the information about the applied BGO/FGO modification scalar m_{G} shell be provided as the SAOC decoder output. The corresponding output parameter interface of the SAOC decoder shall be established in a direct, un-quantized way, where the decoder limited modification gain scalar m_{G} is represented using binary32 (single) floating point format (IEEE 754-2008).

7.10 MBO processing

7.10.1 General

A multi-channel background object (MBO) is an MPS mono or stereo downmix that is part of the SAOC downmix. The associated MPS bitstream can be conveyed either parallel to the SAOC bitstream, i.e. according to the MPS standard (ISO/IEC 23003-1), or it can be embedded in the SAOC bitstream using the **bsSaocExtType**==2 mechanism. As opposed to using individual SAOC objects for each channel in a multi-channel signal, an MBO can be used enabling SAOC to more efficiently handle a multi-channel object. In the MBO case, the SAOC overhead gets lower as the MBO's SAOC parameters only are related to the downmix channels rather than all the upmix channels.

7.10.2 Decoding process

The following decoding process shall be applied in the case where MPS data is embedded in the SAOC bitstream (i.e. carried by means of the **bsSaocExtType**==2 mechanism).

— If the SAOC decoder supports multi-channel rendering (by means of a subsequent MPS decoder) and if the number of output channels of the SAOC rendering matrix is the same as the number of downmix channels of the MPS bitstream, then the embedded MPS bitstream is send "as is" to the subsequent MPS decoder, and SAOC operates as a normal SAOC decoder (as shown in the right part of Figure 2), sending the SAOC-processed output signal as input into the MPS decoder. Note that SAOC and MPS have to be connected directly in the QMF domain in order to ensure proper time-alignment of the MPS and SAOC side information.

— If the SAOC decoder does not support multi-channel rendering or if the number of output channels of the SAOC rendering matrix is different from the number of downmix channels of the MPS bitstream, then the embedded MPS data is discarded and the SAOC decoding or transcoding (depending upon the number of channels of the rendering matrix) is carried out according to the standard decoding process.

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The following decoding process shall be applied in the case where MPS data and SAOC data are both present independently and in parallel, i.e. when MPS data is not embedded in the SAOC bitstream.

a) If a decoder only implements SAOC, then the standard SAOC decoding process is carried out.

b) If a decoder only implements MPS, then the standard MPS decoding process is carried out.

c) If a decoder implements both SAOC and MPS, then, if the number of output channels of the SAOC rendering matrix is the same as the number of downmix channels, first the SAOC decoding process is applied, directly followed by the MPS decoding process (connected in the QMF domain), i.e. this is exactly the same decoding process as defined for the case where MPS data is embedded in the SAOC bitstream). If the number of output channels of the SAOC rendering matrix is the different from number of downmix channels, then either SAOC decoding (discarding the MPS data) or MPS decoding (discarding the SAOC data) can be applied.

To illustrate the decoding process defined above, an example scenario can be considered, where a stereo SAOC downmix includes the stereo downmix of an MBO and a mono vocal object, where the MBO MPS data is embedded in the SAOC bitstream and where the SAOC decoder supports multi-channel rendering (by means of a subsequent MPS decoder). To obtain a multi-channel rendering of only the MBO ("karaoke mode"), a stereo SAOC rendering matrix can be used that attenuates the vocal object. To obtain a multi-channel rendering of only the vocal object ("solo mode"), a multi-channel SAOC rendering matrix can be used that routes the vocal object to the desired output channels and attenuates the MBO.

7.10.3 MPS bitstream settings for MBO

The MPS parameters for MBO shall be specified according to those of the corresponding SAOC data in order to be compatible in the transcoding process. Table 57 contains the list of variables with the corresponding references to tables defined in ISO/IEC 23003-1.

Table 57 — List of the MPS bitstream variables

MBO MPS configuration parameters	SAOC configuration parameters	Reference[a]
bsSamplingFrequencyIndex **bsSamplingFrequency** **bsFrameLength**	**bsSamplingFrequencyIndex** **bsSamplingFrequency** **bsFrameLength**	Table 5 Table 5 Table 5
[a] Defined in ISO/IEC 23003-1.		

7.11 MCU Combiner

7.11.1 General

To use the SAOC concept for teleconferencing applications, a so-called multipoint control unit (MCU) is required, which is able to combine the signals of several communication partners without decoding/re-encoding the corresponding audio objects. As illustrated in Figure 19, the MCU combines the input SAOC side information streams into one common SAOC bitstream in a way that the parameters representing all audio objects from the input bitstreams are included in the resulting output bitstream. These calculations can be performed in the parameter domain without the need to analyse the downmix signals and introducing no additional delay in the signal processing chain.

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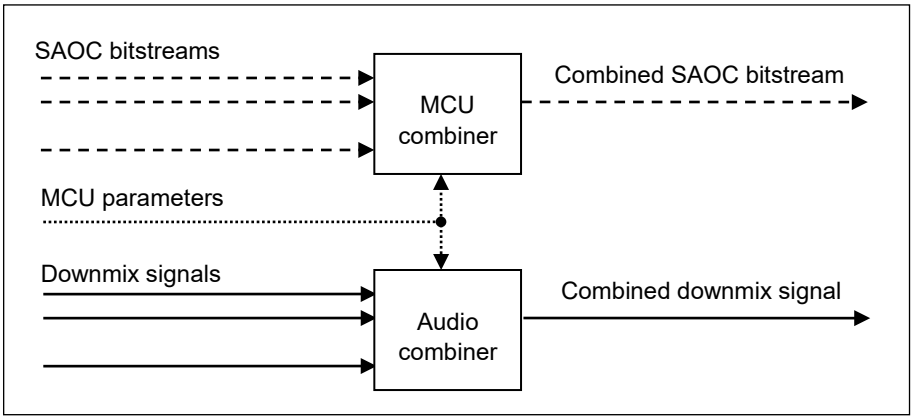

Figure 19 — Outline of the MCU combiner

7.11.2 MCU interface and SAOC parameter estimation

The MCU combiner interface is defined by the input, output and control data. The SAOC parameters (i.e. OLD, IOC, and NRG) of one or several SAOC bitstreams represent the input data for the MCU. The output SAOC bitstream contains the resulting parameters (i.e. OLD, IOC, and NRG) of the combined SAOC bitstream calculated as follows:

$$OLD_j^{comb} = \frac{\mathbf{E}_j}{NRG^{comb}},$$

$$NRG^{comb} = \max_j \left(\mathbf{E}_j \right),$$

$$IOC_{k,j}^{comb} = IOC_{N^{comb}(l,n)N^{comb}(i,n)}^{bs_n},$$

where

$$\mathbf{E}_j = \sum_{N^{comb}(i,n)} \mathbf{F}_{i,n}, \qquad \mathbf{F}_{i,n} = \mathbf{G}_n^{comb} OLD_i^{bs_n} NRG^{bs_n}, \qquad j = N^{comb}\left(i,n\right),$$

$$OLD_i = \mathbf{D}_{\mathrm{OLD}}\left(i,l,m\right), \qquad NRG = \mathbf{D}_{\mathrm{NRG}}\left(l,m\right), \qquad IOC_{i,j} = \mathbf{D}_{\mathrm{IOC}}\left(i,j,l,m\right).$$

The MCU control parameters contain the gains $\mathbf{G}_n^{comb}$ describing the downmix combination process for the weighted mixing, the mapping function $j = N^{comb}\left(i,n\right)$ determining a set and order of audio objects in the combined SAOC bitstream, the parameter for activating the NRG parameter transmission for the combined bitstream, the control parameter describing the resulting downmix mode (i.e. mono or stereo) and the corresponding parameters $\mathbf{D}_{\mathrm{DMG}}^{comb}$ (and $\mathbf{D}_{\mathrm{DCLD}}^{comb}$) describing the downmix.

7.11.3 Energy estimation in the SAOC encoder

All combined SAOC bitstreams shall contain parameters specifying the absolute energy of the object with the highest energy level for a certain time/frequency tile (i.e. **bsTransmitAbsNrg** == 1).

The absolute energy parameter (NRG) is calculated in the SAOC encoder as product of the object signals with the highest energy (normalized according the corresponding time/frequency tiles) according to the following formula:

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$$NRG^{l,m} = \max_i \left(nrg_{i,i}^{l,m} \right), \qquad nrg_{i,j}^{l,m} = \max \left(\frac{\sum_{n \in l} \sum_{k \in m} x_i^{n,k} \left(x_j^{n,k} \right)^*}{\sum_{n \in l} \sum_{k \in m} 1}, \varepsilon^2 \right),$$

where the signal $x_i^{n,k}$ corresponds to the filterbank processing described in ISO/IEC 23003-1:2007, 7.3 for the regular SAOC processing mode and in 7.13.2 for the LP processing mode.

7.11.4 Parameters of the combined bitstreams

The SAOC configuration parameters specifying the frame size and sampling frequency (i.e. **bsFrameLength**, **bsSamplingFrequencyIndex**, **bsSamplingFrequency** and **bsFreqRes**) should be identical for all combined (and resulting) SAOC bitstreams.

7.12 Effects

7.12.1 General

The SAOC effects interface operates on the downmix and therefore is part of the downmix processor of the SAOC transcoder or decoder as shown in Figure 20. The effects interface allows objects or linear combinations of objects to be extracted from the downmix for effects processing. Two types of effects processing interfaces are supported. The first type, referred to as the insert effects interface, allows effects processing to individual objects in the downmix.

The second type, referred to as the send effects interface, allows effect processing on individual objects or linear combinations thereof. For this type, the resulting "wet" signals can be directly added to the SAOC decoder output (see Annex C).

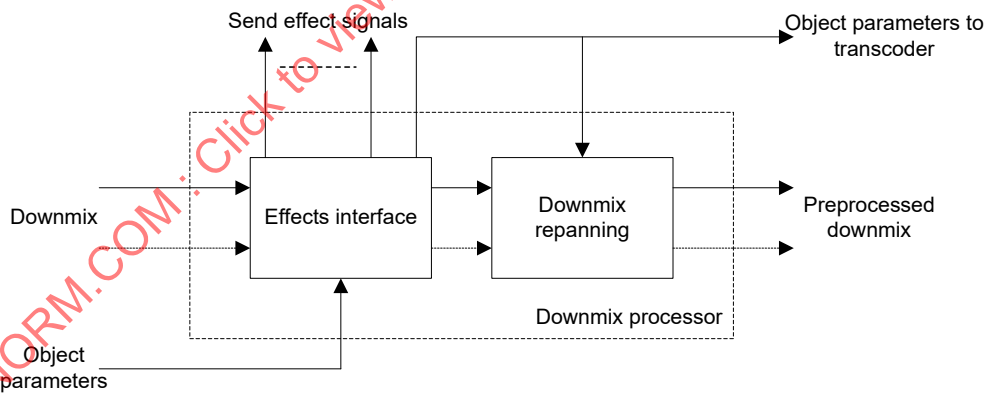

Figure 20 — The effects interface is a part of the downmix processor

A block diagram of the SAOC effects interface is shown in Figure 21. The object splitter, combiner and extractor are described in the following subclauses. The application of the effects on the effect signals (i.e. the signals consisting of objects or linear combinations thereof to which effects processing is to be applied) and the insertion of the send effects signals (i.e. the signals consisting of objects or linear combinations thereof to which send effects processing has been applied) are discussed in Annex C.

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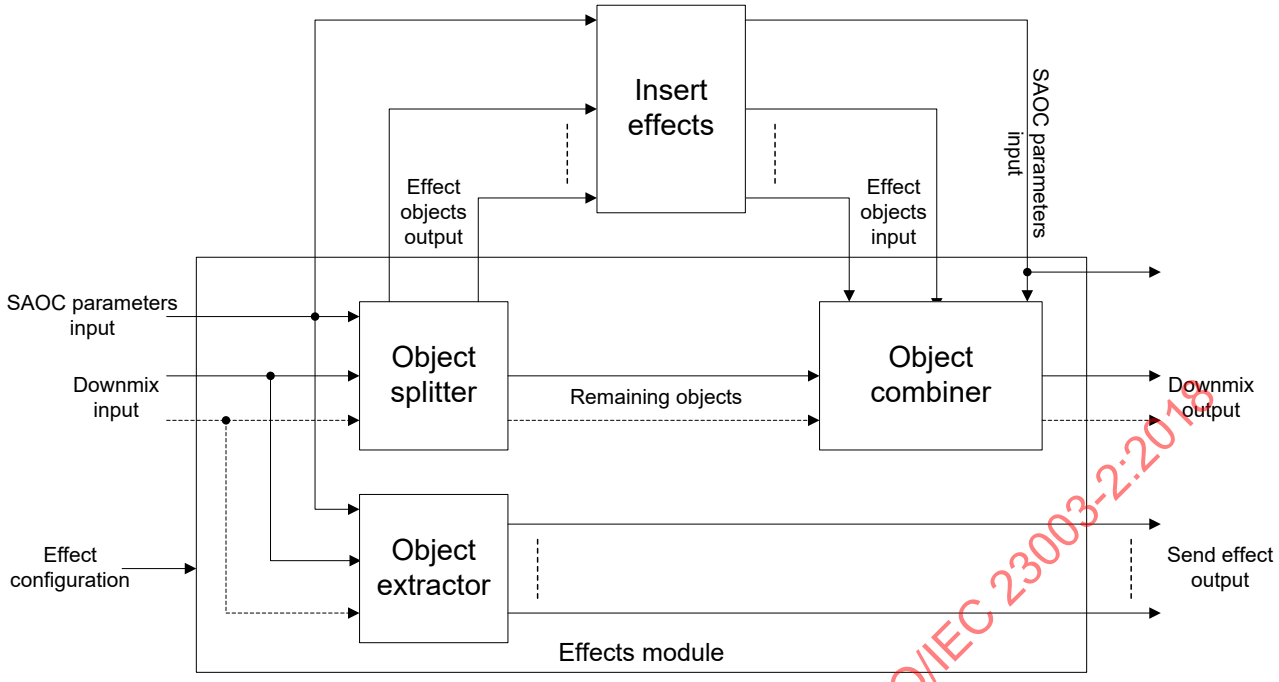

Figure 21 — Effects module in SAOC framework.

7.12.2 Insert effects

The processing block for the insert effects interface consists of an *object splitter* isolating certain objects from the downmix for effect processing and an *object combiner* inserting the effect processed objects back into the downmix. The effect configuration data that is input to the effects module contains an object split vector $\boldsymbol{r}^{insert}$ indicating which objects should be separated from the other objects in the downmix. The object splitter (see Figure 21) splits object $y \in [0, ..., N-1]$ away from the downmix when $r_y^{insert} = 1$. All entries corresponding to objects that are not input to an insert effect are zero. The effect objects are represented by signal vector $\mathbf{x}_{\text{insert}}^{n,k}$ with *numEffObj* elements, defined as:

$$x_{\text{insert},y_e}^{n,k} = \sum_{k=0}^{M-1} w_{insert_k,y_e} x_k^{n,k}$$

where

$$y_e = f_{obj \to eff}(y),$$

$$w_{insert_k,y_e} = \frac{\hat{d}_{k,y}^2 OLD_y}{\sqrt{d_{k,y} OLD_y \sum_{i=0}^{N-1} d_{k,i} OLD_i IOC_{i,y}}}, \quad k = 0,...,M-1,$$

$$\hat{d}_{i,j} = \frac{d_{i,j}}{10^{0.05 DMG_j}},$$

$$numEffObj = \sum_{i=0}^{N-1} r_i^{insert}.$$

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Function $f_{obj \to eff}$ maps object indices to insert effect object indices according to:

$$f_{obj \to eff}(y) = \sum_{i=0}^{y} r_i^{insert} .$$

For a mono downmix case, the downmix matrix **D** is defined as $d_j = d_{0,j} = d_{1,j} = 10^{0.05 DMG_j} / \sqrt{2}$.

The remaining objects are kept in the same format as the downmix and form an additional output of the object splitter. This residual downmix is calculated as follows:

$$x_{res_k} = \left(1 - \sum_{i=0}^{numEffObj-1} w_{insert_k,i}\right) x_k , \quad k = 0,\ldots,M-1 .$$

The effects applied to the effect objects in $\mathbf{x}_{\text{insert}}$ may change the spectro-temporal properties of the objects. Using the SAOC parameters in the bitstream for further processing (transcoding and downmix preprocessing) would then yield suboptimal performance. Therefore, the effects interface provides a SAOC parameter output and input allowing the effects functions to update the parameters to reflect the spectro-temporal properties of the objects after effects processing. These parameters shall be used by the subsequent transcoding and downmix preprocessing.

After effects have been applied, the resulting effect objects $\hat{\mathbf{x}}_{\text{insert}}$ are fed back into the object combiner. This functional block combines the effect objects with the other objects in the residual downmix $\mathbf{x}_k$ which it receives from the object splitter

$$x_{k,eff} = x_{res_k} + \sum_{i=0}^{numEffObj-1} d^2_{k,f_{eff \to obj}(i)} \hat{x}_{\text{insert},i} , \quad k = 0,\ldots,M-1 ,$$

where

$$f_{eff \to obj}(y_e) = y \Big|_{\sum_{i=1}^{y} r_i^{insert} = y_e} .$$

The processing block for the insert effects interface is enabled for the SAOC-DE profile only if no modification range control (MRC) settings are transported in the bitstream (i.e. if **bsDeLimitFlag** == 0).

7.12.3 Send effects

The preparative processing for the send effects consists of an *object extractor* extracting objects or linear combinations of objects from the downmix that are output as send effect channels. As part of the effect configuration, object extraction matrix $\boldsymbol{r}^{send}$ (which may be time- and/or frequency variant) is fed into the effects module indicating the gains per object where each row represents a send effect channel. With this matrix, effect channel $c_e \in [0,\ldots,numEffCh-1]$ is calculated by:

$$x^{n,k}_{\text{send},c_e} = w^{n,k}_{send_L,c_e} x^{n,k}_{L0} + w^{n,k}_{send_R,c_e} x^{n,k}_{R0} ,$$

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where

$$w^{l,m}_{send_L,c_e} = \sqrt{\frac{\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}\hat{d}^2_{0,i}\hat{d}^2_{0,j}r^{send}_{c_e,i}r^{send}_{c_e,j}e_{i,j}}{\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}d_{0,i}d_{0,j}e_{i,j}}}, \quad w^{l,m}_{send_R,c_e} = \sqrt{\frac{\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}\hat{d}^2_{1,i}\hat{d}^2_{1,j}r^{send}_{c_e,i}r^{send}_{c_e,j}e_{i,j}}{\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}d_{1,i}d_{1,j}e_{i,j}}},$$

$$\hat{d}_{i,j} = \frac{d_{i,j}}{10^{0.05DMG_j}}.$$

For a mono downmix case, the downmix matrix **D** is defined as $d_j = d_{0,j} = d_{1,j} = 10^{0.05DMG_j}/\sqrt{2}$.

The processing block for the send effects interface is not enabled for the SAOC-DE profile.

7.13 Low power SAOC processing

7.13.1 General

The SAOC low power (LP) processing mode includes LP tools from MPS such as its partially real valued filter bank, alias reduction and LP decorrelator. In SAOC LP processing mode, the decorrelator is disabled in stereo downmix mode.

7.13.2 Time/frequency transform

In SAOC LP processing mode, the filterbank described in ISO/IEC 23003-1:2007, 6.10.2 shall be used.

7.13.3 Alias reduction

In SAOC LP processing mode, the alias reduction tool described in ISO/IEC 23003-1:2007, 6.10.3 shall be used. However, in ISO/IEC 23003-1:2007, 6.10.3.3, the alias equalization applied to $\mathbf{W}_1^{l,k}$ and $\mathbf{W}_2^{l,k}$ shall be applied instead to:

— $\mathbf{G}$, in the stereo-to-mono, stereo-to-stereo and, stereo-to-transcoding case.

— $\hat{\mathbf{G}}$ and $\mathbf{P}_2$, in the mono-to-mono, mono-to-stereo, and mono-to-binaural case.

— $\mathbf{G}$, in the stereo-to-binaural case.

— $\mathbf{G}_{\mathrm{DE}}$, in the SAOC-DE case.

— $\mathbf{W}_{\mathrm{PDG}}$, in case Post(processing) downmix compensation is active.

7.13.4 Low power decorrelator

In the mono downmix cases, the MPS LP decorrelator should be used according to ISO/IEC 23003-1:2007, 6.10.7.2.

For the stereo downmix cases, the decorrelator is disabled. This should be implemented by the following:

— in the stereo-to-stereo case, always forcing $r_{1,2} > \varepsilon^2$ in subclause 7.5.3.3;

— in the stereo to binaural case, always force $\alpha^{l,m} = \beta^{l,m} = 0$ in 7.5.5.5.

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7.13.5 Residual coding

Residual coding is limited according to ISO/IEC 23003-1:2007, 6.10.8.

7.14 Low delay SAOC processing

7.14.1 Overview

The following subclauses outline the differences of the implementation of the low delay (LD) version of the SAOC decoder/transcoder compared to the regular version outlined in the previous subclauses. An LD QMF filterbank is used and the Nyquist filtering is omitted resulting into a reduced number of processing bands. Furthermore, the decorrelator filters are adapted to the LD operation.

7.14.2 Time/frequency transforms

7.14.2.1 Overview

The LD-SAOC decoder/transcoder employs LD QMF banks to convert time domain signals into subband domain signals and vice versa. Contrary to the regular SAOC decoding mode, the oddly-modulated Nyquist filter bank is omitted for LD-SAOC decoding; see Figure 23.

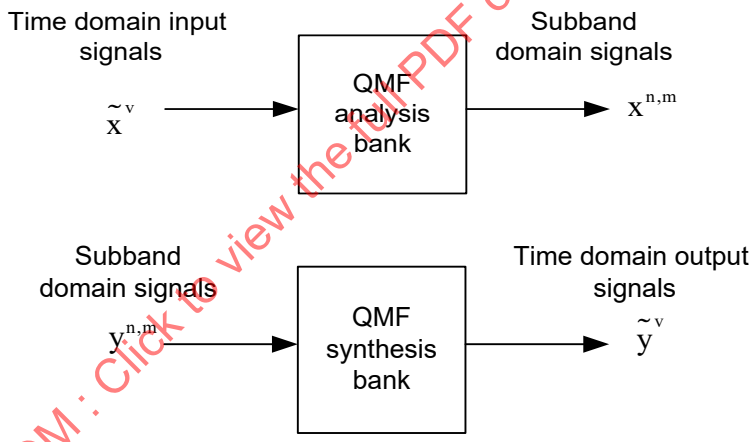

Figure 23 — Time/frequency transforms in LD-SAOC

The LD QMF banks used for LD-SAOC decoding can be derived from the QMF banks defined in ISO/IEC 23003-1:2007, 6.3.2.1 and 6.3.3 by changing the window function and the modulation as described in the following subclauses.

7.14.2.2 Analysis filterbank

The 64-band LD analysis QMF bank is defined by using the QMF LD 256 window function c[i] specified in Table A.21 and by replacing the modulation with

$$M(k,n) = \exp\left(\frac{i\pi(k+0.5)(2n+129)}{128}\right), \qquad \begin{cases} 0 \le k < 64 \\ 0 \le n < 128 \end{cases}.$$

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7.14.2.3 Synthesis filterbank

The 64-band LD synthesis QMF bank is defined by using the QMF LD 256 window function c[i] specified in Table A.21 and by replacing the modulation with

$$\mathrm{M}(k,n)=\frac{1}{64}\exp\left(\frac{i\pi(k+0.5)(2n-255)}{128}\right), \quad \begin{cases}0\le k<64\\0\le n<128\end{cases}.$$

7.14.2.4 Downsampled analysis filterbank

The 32-band LD analysis QMF bank is defined by using window coefficients c_i[i] obtained by linear interpolation

$$c_i(i)=\frac{c(2i+1)+c(2i)}{2}, \qquad 0\le i<320$$

of the QMF LD 256 window function c[i] specified in Table A.21 and by replacing the modulation with

$$\mathrm{M}(k,n)=2\exp\left(\frac{i\pi(k+0.5)(2n+65)}{64}\right), \quad \begin{cases}0\le k<32\\0\le n<64\end{cases}.$$

7.14.2.5 Downsampled synthesis filterbank

The 32-band LD synthesis QMF bank is defined by using window coefficients c_i[i] obtained by linear interpolation

$$c_i(i)=\frac{c(2i+1)+c(2i)}{2}, \qquad 0\le i<320$$

of the QMF LD 256 window function c[i] specified in Table A.21 and by replacing the modulation with

$$\mathrm{M}(k,n)=\frac{1}{64}\exp\left(\frac{i\pi(k+0.5)(2n-127)}{64}\right), \quad \begin{cases}0\le k<32\\0\le n<64\end{cases}.$$

7.14.2.6 Tables

The window function c[i] used for the LD QMF banks is specified in Table A.21.

7.14.2.7 Processing frequency resolution

Due to the omission of the Nyquist filterbank, the number of parameter and processing bands is adapted accordingly. The number of hybrid subbands K is reduced to 64 and the resulting number of processing bands M_{proc} is 23. The number of parameter bands is also adapted accordingly, as described in Table 36.

Table A.22 specifies the mapping from parameter to processing bands and is used instead of ISO/IEC 23003-1:2007, Table 86.

The hybrid to processing band mapping is specified in Table A.23 and is used instead of ISO/IEC 23003-1:2007, Table A.31.

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7.14.2.8 Binaural decoding mode

The processing follows the description of 7.5.5.2 and 7.5.5.5. The HRTF parameters are given by $H_{i,L}^{m}$, $H_{i,R}^{m}$ and ϕ_i^m for each processing band m. The spatial positions for which HRTF parameters are available are characterized by the index i. These parameters are described in ISO/IEC 23003-1, where the index mapping $q(m)$ from ISO/IEC 23003-1:2007, Table A.32 is replaced by $q(m) = m$ as no hybrid filter is applied.

As the number of processing bands is different for the LD decoding mode, the expression $0 \le m \le 11$ in the formulae for interchannel phase difference $\phi_C^{l,m}$ and rotation angle $\alpha^{l,m}$ is replaced by $0 \le m \le 6$.

7.14.2.9 Decorrelation

The decorrelated signals $\mathbf{X}_{\mathrm{d}} = \begin{pmatrix} x_{1d} \\ x_{2d} \end{pmatrix}$ are created from the decorrelator described in ISO/IEC 23003-1:2007, 6.6.2. Following this scheme, the **bsDecorrConfig** == 0 configuration shall be used with a decorrelator index X == 2. For region k_1, as defined in Table B.14, the lattice coefficients are defined in Table B.15. For regions k_2 and k_3, the coefficients are given in Table B.16 and Table B.17.

7.14.2.10 Transcoding to Low Delay MPEG Surround

Transcoding to Low Delay MPEG Surround is specified in Annex B.

8 Transport of SAOC side information

8.1 Overview

Due to its basic principle of operation, SAOC technology requires two data streams for its operation, namely a stream of downmix data (the coded downmix audio signal) and, as side information, a stream of SAOC data (the parametric spatial audio data guiding the SAOC transcoding/decoding process). Depending on the application scenario, both data streams may or may not be conveyed to the SAOC transcoder/decoder as part of a single stream and may or may not be conveyed in a synchronized way. The subsequent subclauses define mechanisms for the transport of spatial data for SAOC for different environments employing MPEG audio and systems to convey a coded downmix audio signal.

8.2 Transport and signalling in an MPEG environment

8.2.1 Time alignment of SAOC frames and downmix coder frames

The SAOC frame length is preferred to be an integer multiple of the frame length of the underlying downmix coder. Asynchronous framing of SAOC data and the downmix data (i.e. different frame lengths) is possible. However, in this case, additional buffering of the SAOC data in the decoder might be needed.

In general, SAOC data is preferably conveyed in such a manner that it is available to the SAOC decoder in time when it is required to process the decoded downmix signals, assuming the most efficient connection of downmix decoder to the SAOC decoder. This is a direct connection of HE-AAC and SAOC in the QMF domain in the case that both use the same number of OMF bands (see 5.4), and a connection in the PCM time domain in all other cases. When HE-AAC and SAOC are connected in the time domain, even though the most efficient connection would have been in the QMF domain, the SAOC parameters have to be delayed accordingly in order to maintain the time alignment between SAOC data and downmix data. Information about this delay is given in 4.5.

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In the case that the SAOC data is embedded in the downmix data stream (see 8.2.2, 8.2.3 and 8.2.4), the temporal relationship between SAOC frames and downmix frames is indicated by the value of saocTimeAlign (see 8.2.5). If saocTimeAlign has the value 0, this indicates that the SAOC data is conveyed in the preferred manner outlined above.

In the case that the downmix data and the SAOC data are conveyed in separate streams, the temporal relationship between SAOC frames and downmix frames is indicated by the time stamps of the access units of the corresponding streams. If a downmix coder other than HE-AAC is used, the time stamp of an access unit carrying an SAOC frame identifies the first PCM sample of the corresponding time domain downmix signal frame that is input to the SAOC decoder. If HE-AAC is used as downmix coder, the time stamp of the SAOC frame identifies the first PCM sample of the corresponding time domain downmix signal frame at the output of the AAC core decoder.

If the transport layer does not provide time stamps, the temporal relationship between the data of these both streams needs to be defined by other means. In case of LATM (see ISO/IEC 14496-3), the first SAOC access unit and the first downmix coder access unit in an AudioMuxElement() are considered to have the same time stamp.

8.2.2 Transport and signalling in an MPEG-4 audio/systems environment

The signalling of the availability of SAOC data is possible by means of an SAOC elementary stream that depends on the elementary stream containing the related coded audio downmix data (as, e.g. indicated by the dependsOn_ES_ID field defined in ISO/IEC 14496-1:2010, 7.2.6.5.2). The actual SAOC data is either conveyed in the SAOC elementary stream or multiplexed into the downmix data stored in the elementary stream upon which the SAOC elementary stream, if present, depends. The latter is specified for MPEG-2/4 AAC payloads (see 8.2.3) and for MPEG-1/2 Layer I/II/III payloads (see 8.2.4).

Backwards compatibility with decoders that can decode the coded audio downmix data but not the SAOC data is achieved in both scenarios.

The interface to ISO/IEC 14496-1 is in line with the specification given in ISO/IEC 14496-3:2009, 1.6. An elementary stream carrying SAOC data is identified by the Audio Object Type "SAOC" (Object Type ID 43) [or Audio Object Type "SAOC-DE" (Object Type ID 45) for SAOC-DE profile]. The AudioSpecificConfig() for this object carries the SaocSpecificConfig() (or SaocDESpecificConfig() for SAOC-DE profile) data and saocPayloadEmbedding, saocDePayloadEmbedding flag that indicates whether the SaocFrame() (or SaocDEFrame() for SAOC-DE profile) payload is conveyed as an elementary stream or embedded into the downmix data, as defined in ISO/IEC 14496-3:2009, 1.6.3.18.

8.2.3 Embedding SAOC data in MPEG-2/4 AAC payloads

SAOC data can be conveyed in the AAC extension_payload() mechanism using extension_type EXT_SAOC_DATA ("1010") [or EXT_SAOC_DE_DATA ("1111") for SAOC-DE profile], as defined in ISO/IEC 13818-7:2006, 8.8 and ISO/IEC 14496-3:2009, 4.5.2.9. The extension_payload() for type EXT_SAOC_DATA (or EXT_SAOC_DE_DATA for SAOC-DE profile) comprises the saoc_extension_data() (or saoc_de_extension_data() for SAOC-DE profile), as defined in ISO/IEC 13818-7:2006, 6.3 and ISO/IEC 14496-3:2009, 4.4.27, which is used to carry a SaocDataFrame(), complete or split into several fragments, using the same syntax elements ancType, ancStart, ancStop and ancDataSegmentByte as defined in 8.2.4, and where in the semantics of the syntax element ancDataSegmentByte, the term AncDataElement is to be replaced by saoc_extension_data (or saoc_de_extension_data for SAOC-DE profile).

This mechanism is backwards compatible with existing AAC decoders and provides implicit signalling. Explicit signalling is possible in an MPEG-4 environment if the SaocSpecificConfig() (or SaocDESpecificConfig() for SAOC-DE profile) is conveyed out-of-band, as, e.g. described in the previous

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subclause. In that case, any in-band SaocSpecificConfig() (or SaocDESpecificConfig() for SAOC-DE profile) shall be identical to the out-of-band one. There must be at least one extension_payload() element with extension_type==EXT_SAOC_DATA (or extension_type==EXT_SAOC_DE_DATA for SAOC-DE profile) in each AAC frame in order to enable immediate implicit signalling. An saoc_extension_data() (or saoc_de_extension_data() for SAOC-DE profile) element can have an empty payload, i.e. cnt==1.

8.2.4 Embedding SAOC data in MPEG-1/2 Layer I/II/III bitstreams

SAOC data can be inserted as ancillary data into an MPEG-1/2 Layer I/II/III bitstream as defined in ISO/IEC 11172-3 and ISO/IEC 13818-3. The AncDataElement() is conveyed in the ancillary data part of an MPEG-1/2 frame. It does not have to be located immediately after the audio_data of that frame. The first bit of the ancSyncword must be byte-aligned with respect to the first bit of the 0xFFF syncword of the MPEG-1/2 frame header. The AncDataElement() must be completely included in the ancillary data of a single MPEG-1/2 frame. There must be at least one AncDataElement() in the ancillary data of each MPEG-1/2 frame in order to enable immediate implicit signalling. An AncDataElement() can have an empty payload, i.e. ancLenBytes==0. If there is more than one AncDataElement() in the ancillary data of an MPEG-1/2 frame, all these AncDataElements() must directly follow each other.

Table 58 — Syntax of AncDataElement()

Syntax	No. of bits	Mnemonic
AncDataElement()		
{		
ancSyncword; /* 0x473 */	**11**	**bslbf**
ancCrcLen;	**1**	**uimsbf**
ancType;	**2**	**uimsbf**
ancStart;	**1**	**uimsbf**
ancStop;	**1**	**uimsbf**
cnt = **ancLenBytes**;	**8**	**uimsbf**
if (cnt==255) {		
cnt += **ancLenBytesAdd**;	**16**	**uimsbf**
}		
if (**ancCrcLen**==0) {		
ancCrcWord;	**8**	**uimsbf**
} else {		
ancCrcWord;	**16**	**uimsbf**
}		
ancCrcWord;	**8**	**uimsbf**
for (i=0; i<cnt; i++) {		
ancDataSegmentByte[i];	**8**	**bslbf**
}		
}		

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ancSyncword Identification syncword. Shall be 0x473.

ancCrcLen Indicates the length of ancCrcWord: 0: 8 bit, 1: 16 bit.

ancType Indicates type of ancillary data, see following table:

Table 59 — ancType

ancType	Meaning
0x0	SaocDataFrame(0) (SAOC frame)
0x1	SaocDataFrame(1) (SAOC header and SAOC frame)
0x2	N/A
0x3	N/A

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ancStart Indicates if data segment begins a data block.

ancStop Indicates if data segment ends a data block.

ancLenBytes Number of bytes in data segment.

ancLenBytesAdd Additional number of bytes in data segment, needed if the data segments contain 255 or more bytes.

ancCrcWord ancCrcWord is defined by the generator polynomial G(x) = x^8+x^2+x+1 and the initial value for the CRC calculation is 0xFF if an 8 bit CRC is signalled by ancCrcLen. For the 16 bit CRC, the generator polynomial is G(x) = x^16 + x^15 + x^2 + 1 and the initial value is 0xFFFF. The CRC covers all bits in the AncDataElement() excluding ancSyncword, ancCrcLen and the ancCrcWord itself.

ancDataSegmentByte The concatenation of all ancDataSegmentByte from consecutive AncDataElement(), starting from the AncDataElement with ancStart==1 up to and including the AncDataElement() with ancStop==1 forms one data block. In case a complete data block is contained in one AncDataElement(), it has ancStart==1 and ancStop==1. If ancType==0x0 or ancType==0x1 then this data block constitutes one SaocDataFrame() syntax element, padded at the end to obtain an integer number of bytes.

8.2.5 SaocDataFrame including optional header

The syntax of "SaocDataFrame()" is given in Table 60.

Table 60 — Syntax of SaocDataFrame()

Syntax	No. of bits	Mnemonic

SaocDataFrame(saocHeaderFlag)
{
numSaocBits = 0;
if (saocHeaderFlag) {
saocTimeAlignFlag;
numSaocBits += 1;
cnt = **saocHeaderLen**;
numSaocBits += 7;
if (cnt==127) {
cnt += **saocHeaderLenAdd**;
numSaocBits += 16;
}
tmpBits = SaocSpecificConfig();
 	
numFillBits = (8*cnt)-tmpBits;
bsFillBits;
numSaocBits += tmpBits+numFillBits;
if (saocTimeAlignFlag) {
saocTimeAlign;
numSaocBits += 16;
}
}
numSaocBits += SaocFrame();
 	
return (numSaocBits);
}
	
	1
	
	7
	
	16
	
	numFillBits
	
	16
	
		uimsbf
		
		uimsbf
		
		uimsbf
		
		Notes 1 and 2
		
		bslbf
		
		simsbf
		
		Notes 1 and 3

NOTE 1 SaocSpecificConfig() and SaocFrame() return the number of bits read. NOTE 2 In case of SAOC-DE profile, SaocSpecificConfig() is replaced by SaocDESpecificConfig(). NOTE 3 In case of SAOC-DE profile, SaocFrame() is replaced by SaocDEFrame().		

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The following semantics apply.

saocHeaderFlag Indicates the presence of a SaocSpecificConfig() element.

saocHeaderLen Indicates the length in bytes of SaocSpecificConfig() plus the following fill bits.

saocHeaderLenAdd Additional length in bytes of SaocSpecificConfig() plus the following fill bits, needed if this length is 127 or more bytes.

bsFillBits Fill bits, to be ignored.

saocTimeAlignFlag Indicates the presence of a saocTimeAlign element. If saocTimeAlignFlag==0 then saocTimeAlign is set to the default value 0.

saocTimeAlign Signed integer in the range -32768...32767, identifying the PCM sample in the time domain output frame of the downmix decoder that corresponds to the beginning of the present SAOC frame (i.e. the first sample of the time domain input signal that is consumed by the SAOC decoding process for the present SAOC frame). The position of the first sample of the output frame is represented as 0. The present SAOC frame is the first SAOC frame that is completed (i.e. ancStop==1) in the present downmix decoder frame. If HE-AAC is used as downmix coder, the time domain output frame of the AAC core decoder (delay-free upsampled by a factor of two in case of normal operation of SAOC with 64 QMF bands) is considered here.

8.3 Transport of SAOC data over PCM channels

8.3.1 General

SAOC data can be conveyed over traditional PCM audio channels through adding a noise signal with specific characteristics to the PCM data. This noise signal, which actually is a randomized version of the SAOC data, can be rendered inaudible by employing subtractive dithered noise shaping controlled by the masked threshold.

8.3.2 Syntax

According to ISO/IEC 23003-1:2007, 7.3.2.

8.3.3 Semantics

According to ISO/IEC 23003-1:2007, 7.3.3.

With the following changes.

bsBDType Indicates the type of buried data according to ISO/IEC 23003-1:2007, 7.3.3 with the addition of the two types 4 and 5 as specified in Table 61.

Table 61 — bsBDType

bsBDType	Type of data
0 ... 3	see ISO/IEC 23003-1:2007
4	SAOC frame, i.e. SaocDataFrame(0)
5	SAOC header+frame, i.e. SaocDataFrame(1)
6 ... 7	see ISO/IEC 23003-1:2007

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bsBDBytes[b] One byte of the payload of BuriedDataElement(). The concatenation of all bsBDBytes from one BuriedDataElement() forms one data block. If bsBDType==0x4 or bsBDType==0x5 then this data block constitutes one SaocDataFrame() syntax element, padded at the end to obtain an integer number of bytes.

8.3.4 Decoding process

8.3.4.1 General

The decoding process consists of two steps. In the first step, the payload from the buried data channel is decoded. In the second step, the payload is converted into a complete SAOC audio bitstream.

In the next subclauses, the decoding of the payload is described.

8.3.4.2 Extraction of buried data payload (including header information)

According to ISO/IEC 23003-1:2007, 7.3.4.2.

8.3.4.3 Synchronization

According to ISO/IEC 23003-1:2007, 7.3.4.3.

8.3.4.4 Allocation

According to ISO/IEC 23003-1:2007, 7.3.4.4.

8.3.4.5 Retrieval of buried data payload

According to ISO/IEC 23003-1:2007, 7.3.4.5.

8.3.4.6 CRC check

According to ISO/IEC 23003-1:2007, 7.3.4.6.

8.3.4.7 SAOC decoding

In the case that the buried data payload is of type SAOC frame or SAOC header+frame, the SaocDataFrame data buried in one PCM buried data frame shall be applied to a PCM frame having the same length as the PCM buried data frame and having an offset in PCM samples specified by the value of saocTimeAlign (see 7.2.5). Furthermore, the first frame shall contain the SaocSpecificConfig (or SaocDESpecificConfig() for SAOC-DE profile), i.e. bsBDType shall have the value 5, and it is recommended, for an encoder, to add the SaocSpecificConfig (or SaocDESpecificConfig() for SAOC-DE profile), to a BuriedDataFrame(), at regular time intervals, such that a decoder is also able to start decoding from another position in the stream.

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9 Transport of predefined rendering information

9.1 General

The preset rendering concept allows to start playback with some initial predefined settings and (if more than one set of the rendering data is available) instantaneously switch between them. A single configuration data structure can contain several independent descriptions of the predefined output audio scenes. The number of the available rendering options is defined by the bitstream syntax variable **bsNumPresets**. Depending on the application specific scenario, the preset information specification can also be omitted. Each preset element contains a simple text string label stored in the text variable

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bsPresetLabel and rendering data, which include the relative output reproduction level and panning position. In view of the fact that the SAOC encoded audio objects can be represented by the mono, stereo or multi-channel signals, the preset rendering information relates to each individual channel of the audio object.

The SAOC bitstream variable **bsPresetMatrix** determines which type of preset data format is applied. More precisely, **bsPresetMatrix** == 1 means that the default matrix-based representation format is applied, whereas **bsPresetMatrix** == 0 means that the preset data have a specific format. The matrix-based format represents the rendering information in the native form used for the SAOC transcoding/decoding. The dequantized rendering parameters obtained from the variable **bsPresetMatrixElements**[i][j] can be unambiguously fed into the rendering interface of the SAOC transcoder/decoder using the following mapping information (see Table 62).

Table 62 — Matrix-based preset parameter quantization table

idx	0	1	2	3	4	5	6	7
bsPresetMatrixElements[i][idx]	$10^{-15.0}$	$10^{-2.4}$	$10^{-2.0}$	$10^{-1.8}$	$10^{-1.6}$	$10^{-1.4}$	$10^{-1.2}$	$10^{-1.0}$
idx	8	9	10	11	12	13	14	15
bsPresetMatrixElements[i][idx]	$10^{-0.8}$	$10^{-0.7}$	$10^{-0.6}$	$10^{-0.5}$	$10^{-0.4}$	$10^{-0.3}$	$10^{-0.2}$	$10^{-0.1}$
idx	16	17	18	19	20	21	22	23
bsPresetMatrixElements[i][idx]	1	$10^{0.1}$	$10^{0.2}$	$10^{0.3}$	$10^{0.4}$	$10^{0.4}$	$10^{0.6}$	$10^{0.7}$
idx	24	25	26	27	28	29	30	31
bsPresetMatrixElements[i][idx]	$10^{0.8}$	$10^{1.0}$	$10^{1.2}$	$10^{1.4}$	$10^{1.6}$	$10^{1.8}$	$10^{2.0}$	$10^{2.4}$

The proposed bitstream structure permits a support of any other alternative data formats containing preset information. Description of such upmix representation approaches remains informative. The specific preset description formats are recognized by the particular identifier label **bsPresetUserDataIdentifier**. The variable **bsPresetUserDataLen** contains the length information for the preset data included into PresetUserDataContainer() bitstream syntax element. This allows the SAOC transcoder/decoder to skip the corresponding part of the preset configuration data if this specific description format is not relevant (not supported) by the transcoder/decoder.

9.2 Rendering information description file format

The preset rendering concept allows to store and exchange user-defined rendering information. The binary file structure is based on the bitstream syntax elements ObjectMetaData() and PresetConfig(). The bitstream variable **bsNumObjects** provides an information about the number of audio objects presented in the described scene and used in ObjectMetaData() and PresetConfig().

The information stored in the variable bsNumObjects and in the element ObjectMetaData() can be also used for identification and compatibility check. For example, the SAOC transcoder/decoder can use the number of audio objects, metadata and other corresponding information obtained from the SAOC bitstream for these purposes.

If it is necessary, the bitstream syntax element RenderingInformation() determining the binary file structure can be encapsulated into a higher level structure depending on the specific realization approach.

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Table 63 — Syntax of RenderingInformation()

Syntax	No. of bits	Mnemonic

RenderingInformation()
{
  bsNumObjects;
 	
  ByteAlign();
  ObjectMetaData();
  ByteAlign();
  PresetConfig();
  ByteAlign();
}
	5	**uimsbf**
		Note
		
		Note
		
		Note

NOTE Described in 6.1.		

10 Conformance testing

10.1 General

This clause specifies conformance criteria for both bitstreams and decoders compliant with the SAOC standard as defined in Clauses 1 to 9 and Annexes A to G. This is done to assist implementers and to ensure interoperability.

10.2 Terms and definitions

The terms and definitions as stated in Clause 3 apply. Furthermore, the following terms and definitions will be used throughout this clause.

bitstream data encoded according to the SAOC standard

conformance test bitstream bitstream used for testing the conformance of an SAOC decoder

10.3 SAOC conformance testing

5.5 defines the SAOC profiles and levels. Some conformance criteria apply to SAOC in general, while others are specific to the specific SAOC profile and its levels. Conformance shall be tested for the level of the profile with which a given bitstream or decoder/transcoder claims to comply.

10.4 Bitstreams

10.4.1 Characteristics

The SAOC audio object type (AOT) can be used in combination with various AOTs.

10.4.2 Test procedure

10.4.2.1 General

An SAOC bitstream shall have the syntax and semantics as specified in Clauses 1 to 9 and Annexes A to G. The present subclause defines the conformance criteria that shall be fulfilled by a compliant bitstream. These criteria are specified for the syntactic elements of the bitstream and for some parameters decoded from the SAOC bitstream payload.

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10.4.2.2 Configuration header

10.4.2.2.1 SAOCSpecificConfig()/SAOCDESpecificConfig()

bsVersion	For restrictions, see 10.4.2.5.
bsSamplingFrequencyIndex	Shall be in the range 0x0...0xc or 0xf. For further restrictions, see 10.4.2.5.
bsSamplingFrequency	For restrictions, see 10.4.2.5.
bsLowDelayMode	For restrictions, see 10.4.2.5.
bsFreqRes	Shall not be encoded with a value of 0.
bsFrameLength	For restrictions, see 10.4.2.5.
bsNumObjects	For restrictions, see 10.4.2.5.
bsNumFGOs	For restrictions, see 10.4.2.5.
bsRelatedTo[i][j]	No restrictions apply.
bsTransmitAbsNrg	No restrictions apply.
bsNumDmxChannels	For restrictions, see 10.4.2.5.
bsTttDualMode	No restrictions apply.
bsTttBandsLow	Shall not be encoded with a value larger than the value of numBands as given by Table 36.
bsPdgFlag	No restrictions apply.
bsOneIOC	No restrictions apply.
bsDcuFlag	For restrictions, see 10.4.2.5.
bsDcuMandatory	No restrictions apply.
bsDcuDynamic	No restrictions apply.
bsDcuMode	No restrictions apply.
bsDcuParam	No restrictions apply.
bsDeLimitFlag	For restrictions, see 10.4.2.5
bsDeLimitFgo	No restrictions apply.
bsDeLimitBgo	No restrictions apply.

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10.4.2.2.2 SAOCExtensionConfigData()

bsSaocExtType	No restrictions apply. Note that in case of values indicated as “N/A” in Table 49, the parsing function SAOCExtensionConfigData(**bsSaocExtType**) shall return the value 0, such that possibly present data is read as **bsFillBits** (i.e. skipped) and correct parsing of the bitstream can continue.
bsSaocExtLen	No restrictions apply.
bsSaocExtLenAdd	No restrictions apply.
bsSaocExtLenAddAdd	No restrictions apply.
bsFillBits	No restrictions apply.

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10.4.2.2.3 SAOCExtensionConfigData(0)

10.4.2.2.3.1 General

The syntactic element SAOCExtensionConfigData(0) shall not be present in case of low delay profile. This syntactic element shall not be present in case of baseline and dialogue enhancement profiles of level 1. Furthermore, this syntactic element shall not be present if the helper variable numSlots has a value that is not listed in ISO/IEC 23003-1:2007, Table 55. Furthermore, if this syntactic element is present, the bitstream shall fulfil the requirements outlined in ISO/IEC 23003-1:2007, 6.1.13. For further restrictions, see 10.4.2.5.

bsDeLimitFgoEAO No restrictions apply.

bsDeLimitBgoEAO No restrictions apply.

bsDcuFlag2 No restrictions apply.

bsDcuMode2 No restrictions apply.

bsDcuParam2 No restrictions apply.

10.4.2.2.3.2 ResidualConfig()

bsResidualSamplingFrequencyIndex Shall fulfil the requirements outlined in ISO/IEC 23003-1:2007, 6.1.13 and Table 88.

bsResidualFramesPerSAOCFrame Shall fulfil the requirements outlined in ISO/IEC 23003-1:2007, 6.1.13 and Table 87.

bsNumGroupsFGO For restrictions, see 10.4.2.5.

bsResidualPresent[i] No restrictions apply.

bsResidualBands[i] Shall not be encoded with a value larger than the value of **bsTtnBandsLow**[i].

bsTtnDualMode[i] No restrictions apply.

bsTtnBandsLow[i] Shall not be encoded with a value larger than the value of numBands as given by Table 36.

10.4.2.2.4 SAOCExtensionConfigData(1)

No restrictions apply.

10.4.2.2.5 SAOCExtensionConfigData(2)

The syntactic element SAOCExtensionConfigData(2) shall not be present in case of SAOC-DE profile. It shall fulfil the requirements outlined in Table 57.

10.4.2.2.6 SAOCExtensionConfigData(3)

No restrictions apply.

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10.4.2.2.7 SAOCExtensionConfigData(8)

10.4.2.2.7.1 ObjectMetaData()

bsNumByteMetaData[i] No restrictions apply.

bsMetaData[i][j] Shall be encoded in UTF-8 encoding format.

10.4.2.2.8 SAOCExtensionConfigData(9)

10.4.2.2.8.1 PresetConfig()

bsNumPresets No restrictions apply.

bsNumBytePresetLabel[i] No restrictions apply.

bsPresetLabel[i][j] Shall be encoded in UTF-8 encoding format.

bsPresetMatrix No restrictions apply.

10.4.2.2.8.2 PresetMatrixData()

bsPresetMatrixType Shall not be encoded with a value of 3.

bsPresetMatrixElements[i][j] No restrictions apply.

10.4.2.2.8.3 PresetMatrixData()

bsPresetUserDataIdentifier[i] Shall be encoded in UTF-8 encoding format.

bsPresetUserDataLen No restrictions apply.

10.4.2.2.9 SAOCExtensionConfigData(10)

10.4.2.2.9.1 General

The syntactic element SAOCExtensionConfigData(10) shall not be present in case of SAOC-DE profile.

10.4.2.2.9.2 SeparationMetaData()

bsNumSeparationPairs No restrictions apply.

bsSeparationMainObjectID[i] No restrictions apply.

bsSeparationSubObjectID[i] No restrictions apply.

10.4.2.3 Bitstream payload

10.4.2.3.1 SAOCFrame()/SAOCDEFrame()

10.4.2.3.1.1 General

bsIndependencyFlag No restrictions apply.

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10.4.2.3.1.2 SAOCFramingInfo()

bsFramingType No restrictions apply.

bsNumParamSets For restrictions, see 10.4.2.5.

bsParamSlot[i] Shall be in the range 0…**bsFrameLength**.

10.4.2.3.1.3 EcDataSaoc()

bsXXXdataMode[i][j] Shall fulfil the requirements outlined in ISO/IEC 23003-1:2007, 6.1.13. Shall not be encoded with the value 2 if EAO mode (residual coding) is applied.

bsDataPairXXX[i][j] Shall have the value 0 if setIdx == dataSets-1. No further restrictions apply.

bsQuantCoarseXXX[i][j] No restrictions apply.

bsFreqResStrideXXX[i][j] No restrictions apply.

10.4.2.3.1.4 SAOCEcDataPair()

bsPcmCodingXXX[i][j] No restrictions apply.

10.4.2.3.1.5 SAOCDiffHuffData()

bsDiffType No restrictions apply.

bsCodingScheme No restrictions apply.

10.4.2.3.1.6 SAOCHuffData1D()

hcodFirstBand_XXX **bsCodeW** shall have a value out of a set of values as defined by column “codeword” of Tables A.2 and A.3, respectively, and shall have a length as defined by the corresponding entry in column “length”.

hcod1D_XXX_YY **bsCodeW** shall have a value out of a set of values as defined by column “codeword” of Tables A.4 and A.5, respectively, and shall have a length as defined by the corresponding entry in column “length”.

bsSign No restrictions apply.

10.4.2.3.1.7 SAOCHuffData2DFreqPair()

hcodLavIdx **bsCodeW** shall have a value out of a set of values as defined by column “codeword” of ISO/IEC 23003-1:2007, Table A.24 and shall have a length as defined by the corresponding entry in column “length”.

hcodFirstBand_XXX **bsCodeW** shall have a value out of a set of values as defined by column “codeword” of Tables A.2 and A.3, respectively, and shall have a length as defined by the corresponding entry in column “length”.

hcod2D_XXX_YY_FP_LL **bsCodeW** shall have a value out of a set of values as defined by column “codeword” of the applicable table out of Tables A.11 to A.22, and shall have a length as defined by the corresponding entry in column “length”.

hcod1D_XXX_YY **bsCodeW** shall have a value out of a set of values as defined by column “codeword” of Tables A.4 and A.5, respectively, and shall have a length as defined by the corresponding entry in column “length”.

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bsSign No restrictions apply.

10.4.2.3.2 SAOCExtensionFrame()

No restrictions apply. Note that in case of **bsSaocExtType** having values indicated as "N/A" in Table 49, the parsing function SAOCExtensionFrameData(**bsSaocExtType**) shall return the value 0, such that possibly present data is read as **bsFillBits** (i.e. skipped) and correct parsing of the bitstream can continue.

bsSaocExtLen No restrictions apply.

bsSaocExtLenAdd No restrictions apply.

bsFillBits No restrictions apply.

10.4.2.3.3 SAOCExtensionFrameData(0)

bsDeLimitEaoUpdate No restrictions apply.

bsDeLimitFgoEAO No restrictions apply.

bsDeLimitBgoEAO No restrictions apply.

bsDcuDynamicUpdate2 No restrictions apply.

bsDcuMode2 No restrictions apply.

bsDcuParam2 No restrictions apply.

10.4.2.4 Transport of SAOC data

10.4.2.4.1 Transport in an MPEG environment

10.4.2.4.1.1 General

In case of transport of SAOC data in an MPEG-4 environment, the following restrictions apply. In case of SAOCSpecificConfig() (or SAOCDESpecificConfig() for SAOC-DE profile) is conveyed out-of-band, any in-band SAOCSpecificConfig() (or SAOCDESpecificConfig() for SAOC-DE profile) shall be identical to the out-of-band one.

In case of embedding of MPEG SAOC data in MPEG-2/4 AAC payloads, the following restrictions apply. There must be at least one extension_payload() element with extension_type==EXT_SAOC_DATA (or extension_type==EXT_SAOC_DE_DATA for SAOC-DE profile) in each AAC frame in order to enable immediate implicit signalling.

In case of embedding of MPEG SAOC data in MPEG-1/2 Layer I/II/III bistreams, the following restrictions apply. The first bit of the ancSyncword must be byte-aligned with respect to the first bit of the 0xFFF syncword of the MPEG-1/2 frame header. The AncDataElement() must be completely included in the ancillary data of a single MPEG-1/2 frame. There must be at least one AncDataElement() in the ancillary data of each MPEG-1/2 frame in order to enable immediate implicit signalling.

10.4.2.4.1.2 AncDataElement()

ancSyncword Shall be 0x473.

ancType No restrictions apply.

ancStart No restrictions apply.

ancStop No restrictions apply.

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ancLenBytes No restrictions apply.

ancLenBytesAdd No restrictions apply.

ancCrcWord Shall have the value as determined by the procedure specified in 8.2.4.

ancDataSegmentByte A data block formed by concatenation of ancDataSegmentByte as specified in 8.2.4 shall, if ancType==0x0 or ancType==0x1, constitute one SaocDataFrame() syntax element, padded at the end to obtain an integer number of bytes.

10.4.2.4.1.3 SaocDataFrame(saocHeaderFlag)

saocHeaderFlag No restrictions apply.

saocHeaderLen No restrictions apply.

saocHeaderLenAdd No restrictions apply.

bsFillBits No restrictions apply.

saocTimeAlignFlag No restrictions apply.

saocTimeAlign Shall have an absolute value no larger than two times the number of samples in the SAOC PCM frame as defined by **bsFrameLength** and **bsSamplingFrequencyIndex** or **bsSamplingFrequency**.

10.4.2.4.2 Transport over PCM channels

10.4.2.4.2.1 General

In case of transport of SAOC data over PCM channels, the following restrictions apply. The BuriedData() data shall be embedded in the LSBs of the PCM channels. Typically, 16 bit PCM samples are used. However, also other sample precisions shall be supported, e.g. 20 and 24 bits.

10.4.2.4.2.2 BuriedDataHeader()

bsBDSyncword Shall be 0xAA95.

bsBDChannels Shall have the value of the number of PCM channels in which the SAOC data is embedded.

bsBDFramelength Shall define a PCM buried data frame size which is exactly the same as the SAOC PCM frame size defined by **bsFrameLength** and **bsSamplingFrequencyIndex** or **bsSamplingFrequency.**

bdBDSubframes Shall fulfil the restrictions outlined for this syntactic element in 8.3.3.

bsBDReserved Shall be 0.

bsBDAlloc[channel][subframe] Shall not exceed the value of n for n bit PCM samples.

bsBDHeaderCrc Shall fulfil the restrictions outlined for this syntactic element in 8.3.3.

bsBDHeaderPadding Shall be 0.

10.4.2.4.2.3 BuriedDataFrame()

bsBDFramePadding Shall be 0.

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10.4.2.4.2.4 BuriedDataElement()

bsBDType Each BuriedDataFrame() shall at least contain one BuriedDataElement() with **bsBDType** set to the value of 4 or 5. In the case of file based applications, the first frame shall contain a BuriedDataElement() with **bsBDType** set to the value of 5.

bsBDID Shall be set to a value in the range of 0..7, each value shall be used only once in a BuriedDataFrame().

bsBDLengthIdx No restrictions apply.

bsBDLength Shall fulfil the restriction outlined for this syntactic element in 8.3.3.

bsBDBytes Shall contain exactly one SaocDataFrame().

bsBDDataCrc Shall fulfil the restrictions outlined for this syntactic element in 8.3.3.

10.4.2.5 Restrictions depending on profiles and levels

10.4.2.5.1 General

Depending on the profile and level associated with the present SAOC bitstream, further restrictions may apply.

10.4.2.5.2 Baseline SAOC profile

For the Baseline SAOC profile, the following further restrictions apply.

bsSamplingFrequencyIndex Shall be encoded with a value listed in Table 64.

bsSamplingFrequency Shall be encoded with a value listed in Table 64.

bsFrameLength Shall be in the range 3..71.

bsLowDelayMode Shall be 0.

bsNumObjects Shall be encoded with a value listed in Table 64.

bsNumDmxChannels Shall be in the range 0..1.

bsNumEAO Shall be encoded with a value listed in Table 64.

Table 64 — Restrictions for the SAOC Baseline Profile

	Level 1	Level 2	Level 3	Level 4
bsSamplingFrequencyIndex	0x3...0xc, 0xf	0x3...0xc, 0xf	0x3...0xc, 0xf	0x0...0xc, 0xf
bsSamplingFrequency	≤48 000	≤48 000	≤48 000	≤96 000
bsNumObjects	0..7	0..15	0..31	0..31
bsNumEAO	N/A	0..1	0..3	0..3

bsDcuFlag No restrictions apply.

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10.4.2.5.3 Low Delay SAOC profile

For the Low Delay SAOC profile, the following further restrictions apply.

bsSamplingFrequencyIndex Shall be encoded with a value listed in Table 65.

bsSamplingFrequency Shall be encoded with a value listed in Table 65.

bsFrameLength Shall be in the range 3..31.

bsLowDelayMode Shall be 1.

bsNumObjects Shall be encoded with a value listed in Table 65.

bsNumDmxChannels Shall be encoded with a value listed in Table 65.

Table 65 — Restrictions for the SAOC Low Delay Profile

	Level 1	Level 2	Level 3
bsSamplingFrequencyIndex	0x3...0xc, 0xf	0x3...0xc, 0xf	0x3...0xc, 0xf
bsSamplingFrequency	≤48 000	≤48 000	≤48 000
bsNumObjects	0..7	0..31	0..31
bsNumDmxChannels	0	0..1	0..1

bsDcuFlag No restrictions apply.

10.4.2.5.4 Dialogue Enhancement SAOC profile

For the dialogue enhancement SAOC profile, the following further restrictions apply.

bsVersion Shall be 0.

bsSamplingFrequencyIndex Shall be in the range 0x3..0xc or 0xf.

bsSamplingFrequency Shall be <= 48 000.

bsFrameLength Shall be in the range 3..71.

bsNumObjects Shall be in the range 0..5.

bsNumDmxChannels Shall be in the range 0..2.

bsNumFGOs Shall be in the range 0..2.

bsDeLimitFlag Shall be 1.

bsNumEAO Shall be encoded with a value listed in Table 66. If it is present, then it shall be equal to **bsNumFGOs**.

Table 66 — Restrictions for the SAOC Dialogue Enhancement Profile

	Level 1	Level 2
bsNumEAO	N/A	0..2

bsDcuFlag Shall be 0.

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10.5 SAOC decoder/transcoder

10.5.1 Characteristics

10.5.1.1 General

The SAOC decoder/transcoder can be implemented in two different versions:

— high quality (HQ) SAOC;

— low power (LP) SAOC.

10.5.2 Test procedure

10.5.2.1 Downmix decoders

An SAOC decoder/transcoder can be used in combination with a downmix decoder. In this case, the downmix decoder shall fulfill the conformance criteria that are applicable to it. Nevertheless, for the conformance test procedure, the PCM coding shall be applied to a downmix signal.

10.5.2.2 SAOC decoder/transcoder test procedure

With regard to the definition and further details of the conformance criterion RMS/LSB being used to test SAOC decoders/transcoders, reference is made to ISO/IEC 14496.

The conformance test procedure for SAOC decoders/transcoders internally creates a reference for comparison, given the conformance test sequence and the output from the decoder under test as outlined in Figure 21.

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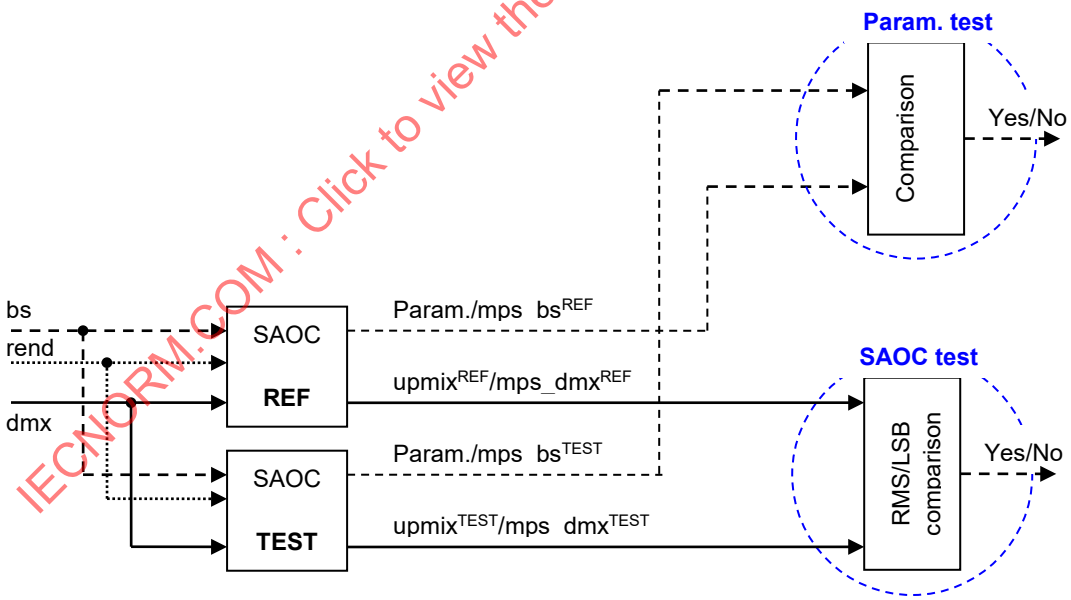

Figure 21 — Block diagram of the SAOC decoding/transcoding conformance test procedure

The relevant signals and data are:

— data from the conformance test sequence:

  — bs: SAOC bitstream from the conformance test sequence;

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  - rend: rendering information from the conformance test sequence;
  - dmx: SAOC downmix signal from the conformance test sequence.
- outputs for comparison from the SAOC decoder/transcoder implementation instances:
  - $upmix^{REF}$/dmx_bs^{REF}: output from the reference SAOC decoder/transcoder;
  - $upmix^{TEST}$/dmx_bs^{TEST}: output from the SAOC decoder/transcoder under test;
  - Param./mps_bs^{REF}: Parametric or/and MPS data from the reference SAOC decoder/transcoder;
  - Param./mps_bs^{TEST}: Parametric or/and MPS data from the SAOC decoder/transcoder under test.
- conformance test modes:
  - SAOC test (RMS/LSB comparison): This module calculates the difference signals between the output from the SAOC decoder/transcoder under test and the internal reference. The maximum amplitude of the difference signal (diff max) as well as the RMS of the difference signal are calculated. The conformance criteria are specified with respect to PCM-sample in the range –32768 ... 32767.
  - Param test (ASCII comparison): This module calculates the difference between the obtained output parameters (e.g. MPS data) from the SAOC decoder/transcoder under test and the internal reference.

10.5.3 Test sequences

To test SAOC decoder/transcoder, ISO/IEC JTC 1/SC 29 supplies a number of test sequences. The naming convention of these bitstreams is as follows. The first part of the name (the part preceding the first underscore) specifies the downmix format. The second part of the name (between the first and the last underscore) specifies the properties of the test sequence in question according to Table 67. For each test sequence, the SAOC test (RMS/LSB comparison) and/or Param test (ASCII comparison) are applied according to Table 68.

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Table 67 — List of SAOC bitstream elements for conformance test sequences

Conformance test sequence	pcm_BLP_x-1-1	pcm_BLP_x-1-2	pcm_BLP_x-1-5	pcm_BLP_x-1-b	pcm_BLP_x-2-1	pcm_BLP_x-2-2	pcm_BLP_x-2-5	pcm_BLP_x-2-b	pcm_BLP_param_4	pcm_BLP_param_5	pcm_BLP_param_7	pcm_BLP_param_10	pcm_BLP_param_14	pcm_BLP_param_20	pcm_LDP_param_4
Downmix sampling frequency	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000
Downmix sample resolution	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
bsSamplingFrequencyIndex	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
bsLowDelayMode	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
bsFreqRes	1	1	1	1	1	1	1	1	7	6	5	4	3	2	7
bsFrameLength	31	31	31	31	31	31	31	31	31	31	31	31	31	31	7
bsNumObjects	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
bsNumFGOs	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsRelatedTo[i][j]	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
bsTransmitAbsNrg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsNumDmxChannels	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
bsTttDualMode	n/a	n/a	n/a	n/a	0	0	0	0	0	0	0	0	0	0	0
bsTttBandsLow	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsPdgFlag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsOneIOC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsDcuFlag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsDcuMandatory	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDcuDynamic	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDcuMode	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDcuParam	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDeLimitFlag	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

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bsDeLimitFgo	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDeLimitBgo	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(0)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(2)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(3)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(8)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(9)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(10)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsFramingType	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsIndependencyFlag	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
bsNumParamSets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsParamSlot[i]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsQuantCoarseXXX[i][j]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SAOCExtensionFrameData(0)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionFrameData(1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionFrameData(2)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionFrameData(3)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

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Conformance test sequence	pcm_LDP_param_5	pcm_LDP_param_7	pcm_LDP_param_9	pcm_LDP_param_12	pcm_LDP_param_15	pcm_LDP_param_23	pcm_BLP_ts_8	pcm_BLP_ts_15	pcm_BLP_ts_16	pcm_BLP_ts_18	pcm_BLP_ts_24	pcm_BLP_ts_30	pcm_BLP_ts_36	pcm_BLP_ts_48	pcm_BLP_ts_60
Downmix sampling frequency	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000
Downmix sample resolution	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
bsSamplingFrequencyIndex	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
bsLowDelayMode	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
bsFreqRes	6	5	4	3	2	1	1	1	1	1	1	1	1	1	1
bsFrameLength	7	7	7	7	7	7	7	14	15	17	23	29	35	47	59
bsNumObjects	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
bsNumFGOs	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsRelatedTo[i][j]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]
bsTransmitAbsNrg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsNumDmxChannels	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
bsTttDualMode	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsTttBandsLow	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsPdgFlag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsOneIOC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsDcuFlag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsDcuMandatory	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDcuDynamic	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDcuMode	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDcuParam	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDeLimitFlag	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDeLimitFgo	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDeLimitBgo	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

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SAOCExtensionConfigData(0)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(2)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(3)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(8)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(9)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(10)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsFramingType	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsIndependencyFlag	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
bsNumParamSets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsParamSlot[i]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsQuantCoarseXXX[i][j]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SAOCExtensionFrameData(0)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionFrameData(1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionFrameData(2)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionFrameData(3)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

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Conformance test sequence	pcm_BLP_ts_64	pcm_BLP_ts_72	pcm_BLP_32khz	pcm_BLP_44khz	pcm_BLP_uqMPS	pcm_BLP_coarse	pcm_BLP_oneIOC	pcm_BLP_PDG	pcm_BLP_EAO	pcm_BLP_DCU	pcm_BLP_MBO	pcm_BLP_MetaData	pcm_BLP_Preset	pcm_BLP_SepData	pcm_BLP_NRG
Downmix sampling frequency	48 000	48 000	32 000	44 100	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000
Downmix sample resolution	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
bsSamplingFrequencyIndex	3	3	5	4	3	3	3	3	3	3	3	3	3	3	3
bsLowDelayMode	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsFreqRes	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
bsFrameLength	63	71	31	31	31	31	31	31	31	31	31	31	31	31	31
bsNumObjects	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
bsNumFGOs	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsRelatedTo[i][j]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]
bsTransmitAbsNrg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
bsNumDmxChannels	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
bsTttDualMode	0	0	0	0	0	n/a	0	0	0	0	0	0	0	0	0
bsTttBandsLow	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsPdgFlag	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
bsOneIOC	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
bsDcuFlag	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
bsDcuMandatory	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1	n/a	n/a	n/a	n/a	n/a
bsDcuDynamic	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1	n/a	n/a	n/a	n/a	n/a
bsDcuMode	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	[e]	n/a	n/a	n/a	n/a	n/a
bsDcuParam	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	[e]	n/a	n/a	n/a	n/a	n/a
bsDeLimitFlag	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDeLimitFgo	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDeLimitBgo	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

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SAOCExtensionConfigData(0)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	+	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	+	n/a	n/a	+	n/a	n/a
SAOCExtensionConfigData(2)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	+	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(3)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	+	n/a	n/a	n/a
SAOCExtensionConfigData(8)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	+	n/a	n/a	n/a
SAOCExtensionConfigData(9)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	+	n/a	n/a
SAOCExtensionConfigData(10)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	+	n/a
bsFramingType	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsIndependencyFlag	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
bsNumParamSets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsParamSlot[i]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsQuantCoarseXXX[i][j]	0	0	0	0	0	g	0	0	0	0	0	0	0	0	0
SAOCExtensionFrameData(0)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	+	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionFrameData(1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	+	n/a	n/a	+	n/a	n/a
SAOCExtensionFrameData(2)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	+	n/a	n/a	n/a	n/a
SAOCExtensionFrameData(3)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	+	n/a	n/a	n/a

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Conformance test sequence	pcm_DEP_x-3-3	pcm_DEP_param_4	pcm_DEP_param_5	pcm_DEP_param_7	pcm_DEP_param_10	pcm_DEP_param_14	pcm_DEP_param_20	pcm_DEP_ts_8	pcm_DEP_ts_15	pcm_DEP_ts_16	pcm_DEP_ts_18	pcm_DEP_ts_24	pcm_DEP_ts_30	pcm_DEP_ts_36	pcm_DEP_ts_48
Downmix sampling frequency	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000	48 000
Downmix sample resolution	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
bsSamplingFrequencyIndex	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
bsLowDelayMode	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsFreqRes	1	7	6	5	4	3	2	1	1	1	1	1	1	1	1
bsFrameLength	31	31	31	31	31	31	31	7	14	15	17	23	29	35	47
bsNumObjects	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
bsNumFGOs	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
bsRelatedTo[i][j]	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
bsTransmitAbsNrg	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsNumDmxChannels	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
bsTttDualMode	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsTttBandsLow	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsPdgFlag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsOneIOC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsDcuFlag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsDcuMandatory	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDcuDynamic	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDcuMode	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDcuParam	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsDeLimitFlag	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
bsDeLimitFgo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsDeLimitBgo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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SAOCExtensionConfigData(0)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(2)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(3)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(8)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(9)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionConfigData(10)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsFramingType	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsIndependencyFlag	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
bsNumParamSets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bsParamSlot[i]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
bsQuantCoarseXXX[i][j]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SAOCExtensionFrameData(0)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionFrameData(1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionFrameData(2)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SAOCExtensionFrameData(3)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

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Conformance test sequence	pcm_DEP_ts_60	pcm_DEP_ts_64	pcm_DEP_ts_72	pcm_DEP_32khz	pcm_DEP_44khz	pcm_DEP_coarse	pcm_DEP_oneIOC	pcm_DEP_MRC	pcm_DEP_PDG	pcm_DEP_varParm	pcm_DEP_EAO				
Downmix sampling frequency	48 000	48 000	48 000	32 000	44 100	48 000	48 000	48 000	48 000	48 000	48 000				
Downmix sample resolution	16	16	16	16	16	16	16	16	16	16	16				
bsSamplingFrequencyIndex	3	3	3	5	4	3	3	3	3	3	3				
bsLowDelayMode	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
bsFreqRes	1	1	1	1	1	1	1	1	1	1	1				
bsFrameLength	59	63	71	31	31	31	31	31	31	31	31				
bsNumObjects	4	4	4	4	4	4	4	4	4	4	4				
bsNumFGOs	1	1	1	1	1	1	1	1	1	1	1				
bsRelatedTo[i][j]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[c]	[b]				
bsTransmitAbsNrg	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
bsNumDmxChannels	2	2	2	2	2	2	2	2	2	2	2				
bsTttDualMode	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
bsTttBandsLow	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
bsPdgFlag	0	0	0	0	0	0	0	0	1	0	0				
bsOneIOC	0	0	0	0	0	0	1	0	0	0	0				
bsDcuFlag	0	0	0	0	0	0	0	0	0	0	0				
bsDcuMandatory	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
bsDcuDynamic	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
bsDcuMode	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
bsDcuParam	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
bsDeLimitFlag	1	1	1	1	1	1	1	1	1	1	1				
bsDeLimitFgo	0	0	0	0	0	0	0	[f]	0	0	0				
bsDeLimitBgo	0	0	0	0	0	0	0	[f]	0	0	0				

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SAOCExtensionConfigData(0)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	+				
SAOCExtensionConfigData(1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
SAOCExtensionConfigData(2)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
SAOCExtensionConfigData(3)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
SAOCExtensionConfigData(8)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
SAOCExtensionConfigData(9)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
SAOCExtensionConfigData(10)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
bsFramingType	0	0	0	0	0	0	0	0	0	1	0				
bsIndependencyFlag	1	1	1	1	1	1	1	1	1	1	1				
bsNumParamSets	0	0	0	0	0	0	0	0	0	[d]	0				
bsParamSlot[i]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	+	n/a				
bsQuantCoarseXXX[i][j]	0	0	0	0	0	[g]	0	0	0	0	0				
SAOCExtensionFrameData(0)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	+				
SAOCExtensionFrameData(1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
SAOCExtensionFrameData(2)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
SAOCExtensionFrameData(3)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				

[a] The bitstream variable **bsRelatedTo**[i][j] is specified accordingly to appropriately describe inter-object correlations between left and right channels of 10 stereo input audio objects.

[b] The bitstream variable **bsRelatedTo**[i][j] is specified accordingly to appropriately describe inter-object correlations between left and right channels of 2 available stereo input audio objects.

[c] The bitstream variable **bsRelatedTo**[i][j] is specified accordingly to describe parametrization assuming no inter-object correlations between any input audio objects.

[d] The bitstream variable **bsNumParamSets** is specified accordingly to describe the variable number of parameter data sets in a frame.

[e] The bitstream variables **bsDcuMode** and **bsDcuParam** are specified according to the desired distortion control settings and updated dynamically if **bsDcuDynamicUpdate** == 1.

[f] The bitstream variables **bsDeLimitFgo** and **bsDeLimitBgo** are specified according to the desired modification range control limits and updated dynamically if **bsDeLimitUpdate** == 1.

[g] The bitstream variables **bsQuantCoarseXXX**[i][j] are specified accordingly to describe the use of coarse and fine parameter quantization modes.

+ IT denotes that the data for the corresponding bitstream element is available.

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Table 68 — List of SAOC conformance RMS/LSB criteria

Conformance test sequence	pcm_BLP_x-1-1	pcm_BLP_x-1-2	pcm_BLP_x-1-5	pcm_BLP_x-1-b	pcm_BLP_x-2-1	pcm_BLP_x-2-2	pcm_BLP_x-2-5	pcm_BLP_x-2-b	pcm_BLP_param_4	pcm_BLP_param_5	pcm_BLP_param_7	pcm_BLP_param_10	pcm_BLP_param_14	pcm_BLP_param_20	pcm_LDP_param_4
SAOC de/transcoding mode	mono	stereo	multichannel	binaural	mono	stereo	multichannel	binaural	stereo	stereo	stereo	stereo	stereo	stereo	stereo
SAOC decoding test	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Diff max (HQ)	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
RMS (HQ)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Diff max (LP)	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
RMS (LP)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
ASCII test	no	no	yes	no	no	no	yes	no	no	no	no	no	no	no	no
Conformance test sequence	**pcm_LDP_param_5**	**pcm_LDP_param_7**	**pcm_LDP_param_9**	**pcm_LDP_param_12**	**pcm_LDP_param_15**	**pcm_LDP_param_23**	**pcm_BLP_ts_8**	**pcm_BLP_ts_15**	**pcm_BLP_ts_16**	**pcm_BLP_ts_18**	**pcm_BLP_ts_24**	**pcm_BLP_ts_30**	**pcm_BLP_ts_36**	**pcm_BLP_ts_48**	**pcm_BLP_ts_60**
SAOC de-/transcoding mode	stereo	stereo	stereo	stereo	stereo	stereo	stereo	stereo	stereo	stereo	stereo	stereo	stereo	stereo	stereo
SAOC decoding test	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Diff max (HQ)	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
RMS (HQ)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Diff max (LP)	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
RMS (LP)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
ASCII test	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
Conformance test sequence	**pcm_BLP_ts_64**	**pcm_BLP_ts_72**	**pcm_BLP_32khz**	**pcm_BLP_44khz**	**pcm_BLP_uqMPS**	**pcm_BLP_coarse**	**pcm_BLP_oneIOC**	**pcm_BLP_PDG**	**pcm_BLP_EAO**	**pcm_BLP_DCU**	**pcm_BLP_MBO**	**pcm_BLP_MetaData**	**pcm_BLP_Preset**	**pcm_BLP_SepData**	**pcm_BLP_NRG**
SAOC de-/transcoding mode	stereo	stereo	stereo	stereo	multichannel	stereo	stereo	stereo	stereo	stereo	stereo	stereo	stereo	stereo	stereo
SAOC decoding test	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	no	no
Diff max (HQ)	32	32	32	32	32	32	32	32	32	32	n/a	n/a	n/a	n/a	n/a
RMS (HQ)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	n/a	n/a	n/a	n/a	n/a

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Diff max (LP)	32	32	32	32	32	32	32	32	32	32	n/a	n/a	n/a	n/a	n/a
RMS (LP)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	n/a	n/a	n/a	n/a	n/a
ASCII test	no	no	no	no	yes	no	no	no	no	no	yes	yes	yes	yes	yes
Conformance test sequence	**pcm_DEP_x-3-3**	**pcm_DEP_param_4**	**pcm_DEP_param_5**	**pcm_DEP_param_7**	**pcm_DEP_param_10**	**pcm_DEP_param_14**	**pcm_DEP_param_20**	**pcm_DEP_ts_8**	**pcm_DEP_ts_15**	**pcm_DEP_ts_16**	**pcm_DEP_ts_18**	**pcm_DEP_ts_24**	**pcm_DEP_ts_30**	**pcm_DEP_ts_36**	
SAOC de-/transcoding mode	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	
SAOC decoding test	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	
Diff max (HQ)	32	32	32	32	32	32	32	32	32	32	32	32	32	32	
RMS (HQ)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
Diff max (LP)	32	32	32	32	32	32	32	32	32	32	32	32	32	32	
RMS (LP)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
ASCII test	no	no	no	no	no	no	no	no	no	no	no	no	no	no	
Conformance test sequence	**pcm_DEP_ts_48**	**pcm_DEP_ts_60**	**pcm_DEP_ts_64**	**pcm_DEP_ts_72**	**pcm_DEP_32khz**	**pcm_DEP_44khz**	**pcm_DEP_coarse**	**pcm_DEP_oneIOC**	**pcm_DEP_MRC**	**pcm_DEP_PDG**	**pcm_DEP_varParm**	**pcm_DEP_EAO**			
SAOC de-/transcoding mode	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel	3-channel			
SAOC decoding test	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes			
Diff max (HQ)	32	32	32	32	32	32	32	32	32	32	32	32			
RMS (HQ)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9			
Diff max (LP)	32	32	32	32	32	32	32	32	32	32	32	32			
RMS (LP)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9			
ASCII test	no	no	no	no	no	no	no	no	no	no	no	no			

yes It denotes that the specified testing method is applicable for the given conformance sequence.

no It denotes that the specified testing method is NOT applicable for the given conformance sequence.

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11 Reference software

11.1 Reference software structure

11.1.1 General

This clause contains simulation software for SAOC as defined in Clauses 1 to 9 and Annex A to Annex G. This software has been derived from verification models used in the process of developing the standard.

Reference software is normative in the sense that it correctly implements the SAOC transcoding/decoding processes described in this document. Complying implementations indicated in this document are not expected to follow the algorithms or the programming techniques used by the reference software. Although the decoding software is considered normative, it cannot add anything to the textual technical description of SAOC included in this document.

The software contained in this clause and in Annex G is divided into three categories:

a) **Bitstream decoding software** is catalogued in 11.2. This software accepts bitstreams encoded according to the normative specification given in this document and decodes the streams into the audio signals associated with each bitstream. While this software appears in the normative part of this document, attention is drawn to the fact that the implementation techniques used in this software are not considered normative, several different implementations could produce the same result, but the software is considered normative in that it correctly implements the SAOC decoding processes described in this document.

b) **Bitstream encoding software** is catalogued in Annex G. This software creates bitstreams from associated audio signals. The encoders are provided as a means to obtain bitstreams with the normative syntax described in this document. The techniques used for encoding are not specified by this document and the quality and complexity of these encoders has not been optimized.

c) **Utility software** is catalogued in Annex G. This software was found useful by the developers of this document, but may not conform to the normative specifications given in this document.

File locations in the source tree given in this document are expressed relative to the location of the corresponding reference software package available at http://standards.iso.org/iso-iec/23003/-2/ed-2/en.

11.1.2 Copyright disclaimer for software modules

Each source code module in this document contains a copyright disclaimer which shall not be removed from the source code module. The generic version of this disclaimer is provided below.

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11.2 Bitstream decoding software

11.2.1 General

The provided bitstream decoding software is a normative reference implementation of the respective specification.

11.2.2 SAOC decoding software

Location	Content
saoc2mps	SAOC transcoder/decoder
mcu	SAOC MCU combiner
mp4spatialdec	LD-MPS decoder

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Annex A
(normative)

Tables

A.1 Huffman tables

The function *1Dhuff_dec()* is used as:

data = 1Dhuff_dec(hcod_huff, codeword),

where *hcod_huff* is the selected Huffman table and *codeword* is the word read from the bitstream. The returned value *data* is a Huffman table index corresponding to a specific code word, with the Huffman table offset value subtracted. The offset value is specified for each Huffman table in Table A.1.

Similarly the function *2Dhuff_dec()* is used as:

(data0, data1) = 2Dhuff_dec(hcod_huff, codeword),

where *hcod_huff* is the selected Huffman table and *codeword* is the word read from the bitstream. The returned values *data0* and *data1* is the corresponding Huffman table index Idx0 and Idx1 corresponding to a specific code word with the Huffman table offset value subtracted. The offset value is specified for each Huffman table in Table A.1.

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Table A.1 — Huffman table overview

Table name	Offset	LAV	Notes
hcodFirstBand_OLD	15	15	
hcodFirstBand_NRG	0	12	Note
hcod1D_OLD_YY	0	15	Note
hcod1D_NRG_YY	0	12	Note
hcod2D_NRG_DT_ZZ_LL_escape	N/A	N/A	
hcod2D_NRG_DT_ZZ_LL_escape	N/A	N/A	
hcod2D_NRG_DT_ZZ_LL_escape	N/A	N/A	
hcod2D_NRG_DF_ZZ_03	0	3	Note
hcod2D_NRG_DF_ZZ_05	0	5	Note
hcod2D_NRG_DF_ZZ_07	0	7	Note
hcod2D_NRG_DF_ZZ_09	0	9	Note
hcod2D_OLD_YY_ZZ_01	0	1	Note
hcod2D_OLD_YY_ZZ_03	0	3	Note
hcod2D_OLD_YY_ZZ_05	0	5	Note
hcod2D_OLD_YY_ZZ_07	0	7	Note
hcod2D_NRG_DT_ZZ_03	0	3	Note
hcod2D_NRG_DT_ZZ_06	0	6	Note
hcod2D_NRG_DT_ZZ_09	0	9	Note
hcod2D_NRG_DT_ZZ_12	0	12	Note
hcod1D_ICC_Diff	0	7	Note
hcodLavIdx	0	N/A	
NOTE Data can only have non-negative values for this table.			

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Table A.2 — hcodFirstBand_OLD

Index	length	codeword (hexadecimal)	Index	length	codeword (hexadecimal)
0	1	0x00	8	6	0x22
1	5	0x1e	9	5	0x10
2	5	0x12	10	6	0x2e
3	5	0x14	11	6	0x2f
4	5	0x15	12	6	0x23
5	5	0x16	13	6	0x26
6	5	0x1f	14	6	0x27
7	3	0x06	15	4	0x0e

Table A.3 — hcodFirstBand_NRG

Index	length	codeword (hexadecimal)	Index	length	codeword (hexadecimal)
0	11	0x67e	32	8	0x0ce
1	12	0x8fe	33	7	0x007
2	12	0x8ff	34	7	0x04e
3	11	0x67f	35	7	0x05e
4	11	0x2fe	36	7	0x05f
5	11	0x47e	37	7	0x077
6	10	0x17e	38	7	0x066
7	11	0x2ff	39	6	0x002
8	10	0x23e	40	6	0x00e
9	10	0x33e	41	6	0x027
10	9	0x0be	42	5	0x002
11	9	0x11e	43	5	0x00a
12	9	0x19e	44	5	0x012
13	8	0x05e	45	5	0x018
14	8	0x08e	46	5	0x01c
15	7	0x006	47	5	0x016
16	7	0x02e	48	5	0x00f
17	7	0x076	49	5	0x000
18	6	0x006	50	6	0x037
19	6	0x012	51	5	0x004
20	6	0x036	52	5	0x00d
21	5	0x00e	53	5	0x01a
22	5	0x014	54	5	0x010
23	5	0x00c	55	5	0x005
24	6	0x03e	56	5	0x008
25	6	0x03f	57	6	0x032
26	5	0x015	58	6	0x007
27	5	0x006	59	6	0x022
28	6	0x03c	60	6	0x013
29	6	0x016	61	6	0x03a
30	6	0x026	62	6	0x00f
31	6	0x02e	63	6	0x03d

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Table A.4 — hcod1D_OLD_YY

Index	DF		DT	
	length	codeword	length	codeword
0	1	0x000	1	0x000
1	3	0x006	2	0x002
2	3	0x004	4	0x00e
3	4	0x00e	4	0x00c
4	4	0x00a	5	0x01e
5	5	0x01e	5	0x01a
6	5	0x016	6	0x03e
7	5	0x01f	5	0x01b
8	7	0x05c	8	0x0fc
9	8	0x0be	9	0x1fc
10	7	0x05d	9	0x1fa
11	8	0x0bc	9	0x1fb
12	9	0x17e	10	0x3fe
13	9	0x17a	10	0x3ff
14	9	0x17b	9	0x1fd
15	9	0x17f	9	0x1fe

Table A.5 — hcod1D_NRG_YY

Index	DF		DT	
	length	codeword	length	codeword
0	3	0x000006	2	0x000000
1	2	0x000000	2	0x000002
2	3	0x000007	3	0x000006
3	3	0x000004	3	0x000002
4	3	0x000002	4	0x00000e
5	4	0x00000a	5	0x00001e
6	4	0x000006	5	0x00000e
7	5	0x000016	5	0x00000c
8	5	0x00000e	6	0x00003e
9	6	0x00002e	6	0x00001e
10	6	0x00001e	6	0x00001a
11	7	0x00005e	7	0x00007e
12	7	0x00003e	7	0x00003e
13	8	0x0000be	7	0x000036
14	9	0x00017e	8	0x0000fe
15	9	0x0000fe	8	0x00007e
16	9	0x0000fc	8	0x00006e
17	10	0x0002fe	9	0x0000fe
18	10	0x0001fe	9	0x0000de
19	11	0x0005fe	10	0x0003fe
20	10	0x0001fa	10	0x0003fc
21	11	0x0003f6	10	0x0001fe
22	11	0x0003fe	10	0x0001be
23	11	0x0003f7	11	0x0007fa
24	12	0x000bfe	11	0x0003fe
25	12	0x0007fe	11	0x00037e
26	13	0x0017fe	11	0x00037f
27	14	0x001ffe	12	0x000ffc
28	14	0x001fff	12	0x000ffe
29	14	0x001ffc	12	0x000ff6
30	15	0x005ffe	12	0x0007fe
31	15	0x003ffa	13	0x000ffe
32	17	0x00ffee	13	0x000fff

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Table A.5 (*continued*)

Index	DF		DT	
	length	codeword	length	codeword
33	15	0x005fff	14	0x003ffc
34	22	0x1ffde8	15	0x007ffc
35	16	0x007ff6	15	0x007ffd
36	14	0x002ffe	14	0x003ff6
37	22	0x1ffde9	15	0x007ffe
38	22	0x1ffdea	15	0x007fea
39	22	0x1ffdeb	14	0x003fdc
40	22	0x1ffdec	16	0x00fff6
41	22	0x1ffded	14	0x003ff7
42	22	0x1ffdee	16	0x00fffe
43	22	0x1ffdef	15	0x007feb
44	22	0x1ffdf0	17	0x01fffe
45	22	0x1ffdf1	14	0x003fde
46	22	0x1ffdf2	14	0x003fdd
47	22	0x1ffdf3	14	0x003ff4
48	22	0x1ffdf4	18	0x03fffe
49	22	0x1ffdf5	24	0xffffe
50	22	0x1ffdf6	14	0x003fdf
51	22	0x1ffdf7	16	0x00fff4
52	22	0x1ffdf8	16	0x00fff5
53	22	0x1ffdf9	24	0xfffff
54	22	0x1ffdfa	16	0x00fff7
55	22	0x1ffdfb	20	0x0fffe
56	22	0x1ffdfc	19	0x07fffe
57	22	0x1ffdfd	23	0x7ffff8
58	22	0x1ffdfe	23	0x7ffff9
59	22	0x1ffdff	23	0x7ffffa
60	21	0x0ffef0	23	0x7ffffb
61	21	0x0ffef1	23	0x7ffffc
62	21	0x0ffef2	23	0x7ffffd
63	21	0x0ffef3	23	0x7ffffe

Table A.6 — hcod2D_OLD_YY_ZZ_LL_escape

LL	DF/FP		DT/FP	
	length	codeword	length	codeword
03		N/A		N/A
06		N/A		N/A
09		N/A		N/A
12		N/A		N/A

Table A.7 — hcod2D_NRG_DF_ZZ_LL_escape

LL	DF/FP	
	length	codeword
03		N/A
05		N/A
07		N/A
09		N/A

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Table A.8 — hcod2D_NRG_DT_ZZ_LL_escape

LL	DT/FP	
	length	codeword
03		N/A
06		N/A
09		N/A
12		N/A

Table A.9 — hcod2D_OLD_YY_ZZ_03

Idx0	Idx1	DF/FP		DT/FP	
		length	codeword	length	codeword
0	0	2	0x002	1	0x000
0	1	3	0x006	6	0x03e
0	2	3	0x002	8	0x0de
0	3	3	0x003	8	0x0dc
1	0	3	0x000	5	0x01e
1	1	4	0x00e	4	0x00e
1	2	4	0x002	6	0x036
1	3	5	0x01e	7	0x07e
2	0	6	0x03e	6	0x032
2	1	6	0x00e	7	0x07f
2	2	6	0x00f	5	0x018
2	3	7	0x07e	5	0x01a
3	0	9	0x1fe	8	0x0df
3	1	9	0x1ff	8	0x0dd
3	2	8	0x0fe	6	0x033
3	3	5	0x006	2	0x002

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Table A.10 – hcod2D_OLD_YY_ZZ_06

Idx0	Idx1	DF/FP		DT/FP	
		length	codeword	length	codeword
0	0	1	0x0000	1	0x0000
0	1	5	0x001a	7	0x007e
0	2	6	0x0032	9	0x01ea
0	3	7	0x0066	11	0x07ae
0	4	7	0x0056	13	0x1ef6
0	5	8	0x00ce	16	0xf7fe
0	6	9	0x01f4	16	0xf7ff
1	0	6	0x002e	6	0x003e
1	1	4	0x0008	4	0x000c
1	2	6	0x002a	8	0x00f2
1	3	7	0x006e	9	0x015e
1	4	8	0x00f4	12	0x0f7e
1	5	9	0x01ea	14	0x3dfe
1	6	13	0x1f7e	8	0x00da
2	0	7	0x0057	6	0x002c
2	1	6	0x0026	6	0x003a
2	2	5	0x0016	5	0x0014
2	3	8	0x00fe	10	0x03d6
2	4	8	0x00a6	12	0x0f7a
2	5	12	0x0fbc	8	0x00de
2	6	12	0x0fbd	7	0x005a
3	0	9	0x01f5	7	0x006e
3	1	7	0x0052	6	0x002e
3	2	8	0x00f6	8	0x00f6
3	3	6	0x0028	7	0x0056
3	4	8	0x00f7	9	0x01e6
3	5	8	0x00fc	7	0x005b
3	6	8	0x00ff	6	0x002f
4	0	12	0x0fba	8	0x00f4
4	1	11	0x07dc	7	0x006c
4	2	12	0x0fbe	8	0x00ae
4	3	8	0x00a7	11	0x07af
4	4	6	0x003c	6	0x002a
4	5	7	0x006f	7	0x007f
4	6	7	0x005e	6	0x003b
5	0	14	0x3efe	9	0x01ee
5	1	12	0x0fbb	8	0x00df
5	2	9	0x01f6	13	0x1efe
5	3	8	0x00fd	11	0x07be
5	4	7	0x007c	8	0x00db
5	5	5	0x0018	5	0x001c
5	6	6	0x0036	5	0x001a
6	0	14	0x3eff	9	0x015f
6	1	9	0x01eb	15	0x7bfe
6	2	8	0x00cf	13	0x1ef7
6	3	7	0x005f	11	0x07bc
6	4	6	0x0027	9	0x01e7
6	5	5	0x0012	7	0x0078
6	6	4	0x000e	3	0x0004

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Table A.11 — hcod2D_OLD_YY_ZZ_09

Idx0	Idx1	DF/FP		DT/FP	
		length	codeword	length	codeword
0	0	1	0x00000	1	0x00000
0	1	6	0x00036	7	0x00042
0	2	7	0x0007e	9	0x0015a
0	3	7	0x0005c	11	0x007da
0	4	8	0x000ec	12	0x009ee
0	5	8	0x000c6	14	0x027fe
0	6	7	0x00068	15	0x06f7e
0	7	6	0x0002a	14	0x0279e
0	8	9	0x001d2	19	0x6f7fe
0	9	10	0x003b6	17	0x13dfe
1	0	7	0x00062	6	0x00022
1	1	5	0x00016	5	0x0001e
1	2	7	0x00066	8	0x000ac
1	3	8	0x000ee	10	0x0037e
1	4	8	0x000ae	11	0x004f6
1	5	9	0x0018e	13	0x01bde
1	6	8	0x000d2	13	0x013fe
1	7	10	0x00278	16	0x0defe
1	8	10	0x0031e	19	0x6f7ff
1	9	6	0x00030	11	0x006fa
2	0	7	0x00056	7	0x0005a
2	1	7	0x0006a	6	0x00020
2	2	6	0x00032	6	0x0003a
2	3	8	0x000ce	10	0x003ec
2	4	9	0x001da	11	0x004fa
2	5	8	0x000ea	11	0x004f2
2	6	10	0x0021e	15	0x04f7c
2	7	12	0x00d7e	17	0x1bdfe
2	8	12	0x009f6	11	0x006fb
2	9	11	0x005fe	10	0x0027c
3	0	8	0x0008e	7	0x0004e
3	1	7	0x00040	7	0x0007c
3	2	6	0x00037	8	0x000fe
3	3	6	0x00022	7	0x0006e
3	4	7	0x0004c	10	0x0037c
3	5	10	0x0033e	13	0x013de
3	6	11	0x0077e	14	0x0279f
3	7	11	0x0043e	11	0x0056e
3	8	11	0x005f6	10	0x002be
3	9	11	0x0043f	6	0x00036
4	0	11	0x005f2	8	0x000ff
4	1	10	0x0033f	7	0x0005e
4	2	10	0x003ae	8	0x000fa
4	3	9	0x0017e	7	0x0004a
4	4	9	0x001ae	10	0x0027e
4	5	6	0x00028	14	0x037be
4	6	10	0x003a6	12	0x00fba
4	7	10	0x002fa	10	0x002b6
4	8	10	0x0027a	6	0x00023
4	9	11	0x004fa	7	0x00072
5	0	11	0x0075e	8	0x000e6
5	1	11	0x0074e	7	0x00054
5	2	11	0x0074f	7	0x00076
5	3	10	0x0023e	11	0x007de
5	4	10	0x00279	12	0x00dee
5	5	9	0x0019e	11	0x0056f

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Table A.11 (*continued*)

5	6	10	0x0035e	11	0x006f6
5	7	9	0x0011e	7	0x0005b
5	8	10	0x002fe	7	0x00043
5	9	10	0x003be	7	0x00077
6	0	11	0x0075f	8	0x000e7
6	1	11	0x0077f	6	0x0002c
6	2	10	0x0027c	10	0x002bf
6	3	11	0x005f7	11	0x004fe
6	4	11	0x005ff	14	0x027ff
6	5	10	0x0023f	13	0x01bfe
6	6	5	0x0001c	6	0x0002e
6	7	7	0x00042	8	0x000ae
6	8	7	0x0004a	7	0x00055
6	9	7	0x0004e	7	0x0007e
7	0	10	0x0027e	5	0x0001a
7	1	11	0x006be	10	0x0037a
7	2	10	0x0027f	11	0x006fe
7	3	10	0x0027b	15	0x04f7d
7	4	10	0x003b7	14	0x037fe
7	5	7	0x00041	11	0x007df
7	6	9	0x001de	10	0x00278
7	7	6	0x00024	6	0x00024
7	8	7	0x00046	7	0x0005f
7	9	7	0x0004d	6	0x00026
8	0	12	0x00d7f	11	0x004fb
8	1	11	0x005f3	11	0x007db
8	2	10	0x002f8	17	0x13dff
8	3	9	0x0010e	15	0x04f7e
8	4	8	0x000e8	12	0x009e6
8	5	8	0x00086	12	0x00dfe
8	6	8	0x000d3	11	0x007dc
8	7	7	0x0004b	9	0x001bc
8	8	6	0x0003e	5	0x00014
8	9	7	0x0007f	6	0x00038
9	0	12	0x009f7	12	0x00fbb
9	1	11	0x0063e	18	0x37bfe
9	2	11	0x0063f	16	0x09efe
9	3	8	0x000d6	14	0x037ff
9	4	9	0x001d6	13	0x013ce
9	5	8	0x000af	12	0x009fe
9	6	7	0x0005d	10	0x0027a
9	7	7	0x0005e	9	0x0015e
9	8	6	0x00029	7	0x0004b
9	9	5	0x0001e	4	0x0000c

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Table A.12 — hcod2D_OLD_YY_ZZ_12

Idx0	Idx1	DF/FP		DT/FP	
		length	codeword	length	codeword
0	0	4	0x00000a	2	0x000002
0	1	8	0x0000d6	7	0x000070
0	2	8	0x000074	8	0x000036
0	3	3	0x000000	9	0x00006e
0	4	5	0x000004	11	0x00035e
0	5	6	0x00001a	12	0x000d7e
0	6	7	0x000046	13	0x0003fc
0	7	10	0x0002de	16	0x0045fe
0	8	11	0x0006fc	15	0x0022fe
0	9	7	0x000036	22	0x3cfbf4
0	10	4	0x00000e	22	0x3cfbf5
0	11	6	0x000026	22	0x3cfbf6
0	12	7	0x00006a	22	0x3cfbf7
1	0	7	0x00004e	6	0x00001c
1	1	7	0x00005c	4	0x000000
1	2	7	0x00004a	7	0x000028
1	3	6	0x000022	9	0x0001fa
1	4	4	0x00000c	10	0x0001f6
1	5	6	0x000024	11	0x0000fe
1	6	7	0x00003e	13	0x001d76
1	7	8	0x00006e	14	0x0007fa
1	8	8	0x000075	14	0x0007fb
1	9	7	0x00004f	22	0x3cfbf8
1	10	6	0x000036	22	0x3cfbf9
1	11	4	0x00000f	22	0x3cfbfa
1	12	7	0x00005e	9	0x0001be
2	0	8	0x0000de	7	0x00007a
2	1	7	0x00006e	6	0x00001e
2	2	6	0x00000a	6	0x00003e
2	3	6	0x00001e	9	0x0001e6
2	4	5	0x000006	9	0x000066
2	5	4	0x000004	11	0x00022e
2	6	7	0x000016	12	0x0006be
2	7	11	0x00069e	15	0x0079f6
2	8	7	0x00005d	14	0x003cfa
2	9	7	0x000068	22	0x3cfbfb
2	10	6	0x00001c	16	0x00f3ee
2	11	5	0x00000c	9	0x0001fe
2	12	5	0x00000a	8	0x00006e
3	0	10	0x0002fa	7	0x00003a
3	1	9	0x00017c	6	0x00000e
3	2	6	0x00000e	7	0x000068
3	3	6	0x00000f	7	0x000078
3	4	6	0x00002c	10	0x0001f7
3	5	5	0x000010	11	0x00022c
3	6	11	0x00047c	12	0x000eba
3	7	10	0x0000ba	13	0x0008b6
3	8	11	0x00037c	13	0x0003fe
3	9	12	0x0006fa	22	0x3cfbfc
3	10	19	0x02ebf4	9	0x0001d4
3	11	19	0x02ebf5	8	0x0000de
3	12	19	0x02ebf6	7	0x00002a
4	0	11	0x0005ae	7	0x000024
4	1	10	0x0002d6	6	0x00000a
4	2	10	0x0002d4	7	0x00001a
4	3	10	0x0001de	8	0x00007e

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Table A.12 *(continued)*

4	4	9	0x0000be	8	0x0000f6
4	5	11	0x00047d	11	0x0001be
4	6	10	0x000176	11	0x0001bc
4	7	11	0x0004bc	12	0x0006bf
4	8	12	0x000966	15	0x006bfe
4	9	19	0x02ebf7	9	0x00003e
4	10	19	0x02ebf8	8	0x00005e
4	11	19	0x02ebf9	7	0x000029
4	12	19	0x02ebfa	7	0x000018
5	0	11	0x0002ee	7	0x000026
5	1	10	0x000170	7	0x000074
5	2	11	0x0005fe	7	0x00001e
5	3	11	0x0005f6	8	0x000046
5	4	11	0x000476	9	0x0000be
5	5	9	0x00017e	8	0x0000dc
5	6	11	0x0004b6	11	0x0006be
5	7	12	0x000bee	13	0x001e7c
5	8	11	0x000472	10	0x00038e
5	9	11	0x0005be	9	0x0001de
5	10	11	0x0005af	8	0x0000f7
5	11	12	0x0008fe	8	0x0000f2
5	12	13	0x001a7e	7	0x00002b
6	0	13	0x001a7f	8	0x0000fc
6	1	12	0x000d3e	7	0x000069
6	2	11	0x0002e2	7	0x00000a
6	3	12	0x000dfe	9	0x0001fb
6	4	10	0x0000bb	9	0x0001c6
6	5	11	0x0005ea	10	0x0003ce
6	6	9	0x00005c	10	0x00035e
6	7	12	0x000dff	11	0x0007f6
6	8	11	0x00037a	9	0x000067
6	9	11	0x000474	8	0x000047
6	10	12	0x0006f6	9	0x0001fc
6	11	12	0x0006fb	7	0x00001f
6	12	12	0x0005d6	7	0x00006a
7	0	14	0x00175e	8	0x00006f
7	1	13	0x000bae	7	0x000025
7	2	13	0x0016ae	8	0x00006a
7	3	12	0x000dfc	8	0x0000e6
7	4	12	0x000d36	9	0x0000d6
7	5	12	0x0006fe	11	0x00075c
7	6	12	0x000d37	13	0x001e7e
7	7	9	0x00011e	9	0x0001ff
7	8	10	0x0001df	9	0x0001ae
7	9	11	0x0002ef	9	0x0000f8
7	10	11	0x000473	8	0x0000e2
7	11	11	0x000475	7	0x00002e
7	12	11	0x00047e	6	0x000004
8	0	19	0x02ebfb	8	0x000044
8	1	19	0x02ebfc	7	0x00000e
8	2	19	0x02ebfd	8	0x0000ee
8	3	19	0x02ebfe	8	0x00001e
8	4	19	0x02ebff	10	0x0003fa
8	5	12	0x000bef	14	0x00117e
8	6	11	0x0004be	13	0x001d77
8	7	10	0x0001bc	11	0x00075e
8	8	10	0x00034c	8	0x000032
8	9	11	0x00069a	9	0x0001bf

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Table A.12 *(continued)*

8	10	10	0x000174	8	0x0000dd
8	11	10	0x00017e	7	0x00003b
8	12	10	0x000258	6	0x00000b
9	0	18	0x0175f0	9	0x0001d5
9	1	18	0x0175f1	7	0x000034
9	2	18	0x0175f2	8	0x00006c
9	3	18	0x0175f3	9	0x0000f9
9	4	12	0x0008ff	18	0x03cfbe
9	5	11	0x0004b7	13	0x0008b7
9	6	10	0x000172	12	0x000ebe
9	7	11	0x000477	12	0x000ebf
9	8	11	0x0006fd	10	0x0001ae
9	9	9	0x00012e	7	0x000027
9	10	10	0x00034e	7	0x00000b
9	11	9	0x0000bc	7	0x000072
9	12	9	0x0000bd	6	0x000016
10	0	18	0x0175f4	9	0x0001d6
10	1	18	0x0175f5	8	0x00007f
10	2	18	0x0175f6	9	0x0001df
10	3	12	0x0006ff	22	0x3cfbfd
10	4	12	0x000dfd	13	0x0008be
10	5	11	0x0004bf	13	0x001e7f
10	6	11	0x0002fe	12	0x00045a
10	7	11	0x0005bf	11	0x0001bd
10	8	10	0x00025a	11	0x0007f7
10	9	9	0x00005e	9	0x0000bf
10	10	8	0x0000b4	6	0x000010
10	11	9	0x0001ae	6	0x000006
10	12	9	0x0001be	6	0x000036
11	0	18	0x0175f7	9	0x0001ac
11	1	18	0x0175f8	9	0x0001ad
11	2	12	0x0006f7	22	0x3cfbfe
11	3	11	0x0002e3	22	0x3cfbff
11	4	11	0x0004b2	14	0x0035fe
11	5	11	0x0002ea	16	0x00d7fe
11	6	11	0x0004bd	13	0x0003ff
11	7	10	0x000173	11	0x0001bf
11	8	10	0x0002fe	10	0x00007e
11	9	9	0x0000ee	9	0x0000fa
11	10	9	0x0001af	8	0x0000e7
11	11	7	0x00003f	5	0x00000c
11	12	8	0x0000b6	5	0x000004
12	0	18	0x0175f9	10	0x00038f
12	1	13	0x0016af	21	0x1e7df8
12	2	12	0x000967	16	0x0045ff
12	3	11	0x0002ff	21	0x1e7df9
12	4	12	0x000b56	16	0x00d7ff
12	5	11	0x00037e	17	0x01e7de
12	6	11	0x0005ff	13	0x001afe
12	7	10	0x000238	12	0x00045e
12	8	9	0x00005f	11	0x00079e
12	9	9	0x00016e	9	0x00008a
12	10	8	0x000076	8	0x00006d
12	11	8	0x0000d2	7	0x000076
12	12	6	0x000016	4	0x00000c

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Table A.13 — hcod2D_NRG_DF_ZZ_03

Idx0	Idx1	DF/FP	
		length	codeword
0	0	4	0x0c
0	1	4	0x0d
0	2	4	0x08
0	3	4	0x06
1	0	4	0x0e
1	1	3	0x00
1	2	4	0x0a
1	3	4	0x09
2	0	4	0x07
2	1	4	0x02
2	2	5	0x1e
2	3	4	0x0b
3	0	5	0x06
3	1	5	0x07
3	2	5	0x1f
3	3	3	0x02

Table A.14 — hcod2D_NRG_DF_ZZ_05

Idx0	Idx1	DF/FP	
		length	codeword
0	0	4	0x0006
0	1	4	0x0008
0	2	5	0x0006
0	3	7	0x004a
0	4	8	0x0092
0	5	9	0x005e
1	0	4	0x0007
1	1	3	0x0000
1	2	5	0x0016
1	3	6	0x0026
1	4	7	0x0016
1	5	8	0x002e
2	0	5	0x0008
2	1	5	0x0017
2	2	5	0x0007
2	3	7	0x0048
2	4	7	0x002e
2	5	7	0x007e
3	0	7	0x004b
3	1	6	0x0016
3	2	7	0x004e
3	3	7	0x007f
3	4	6	0x003e
3	5	5	0x000a
4	0	8	0x0093
4	1	8	0x009e
4	2	7	0x002f
4	3	5	0x0004
4	4	5	0x001e
4	5	4	0x000a
5	0	9	0x005f
5	1	8	0x009f
5	2	6	0x000a
5	3	5	0x0009
5	4	4	0x000e
5	5	3	0x0006

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Table A.15 — hcod2D_NRG_DF_ZZ_07

Idx0	Idx1	DF/FP	
		length	codeword
0	0	5	0x00018
0	1	5	0x0001a
0	2	5	0x0000a
0	3	6	0x00002
0	4	7	0x0002e
0	5	8	0x000ce
0	6	6	0x00008
0	7	9	0x000bc
1	0	5	0x0001e
1	1	4	0x00008
1	2	5	0x00014
1	3	6	0x00026
1	4	7	0x0004a
1	5	7	0x0007c
1	6	7	0x00012
1	7	7	0x0001e
2	0	5	0x00002
2	1	5	0x00015
2	2	5	0x00003
2	3	6	0x00016
2	4	7	0x0004e
2	5	8	0x0009e
2	6	9	0x00176
2	7	9	0x001f6
3	0	6	0x00024
3	1	5	0x00000
3	2	6	0x00003
3	3	7	0x0005c
3	4	7	0x0003c
3	5	8	0x000cf
3	6	8	0x000fa
3	7	8	0x000ba
4	0	8	0x000fe
4	1	7	0x0003e
4	2	7	0x0001f
4	3	6	0x0002c
4	4	7	0x00013
4	5	7	0x00066
4	6	7	0x0005e
4	7	6	0x0000e
5	0	9	0x000be
5	1	8	0x00096
5	2	9	0x001f7
5	3	8	0x000ff
5	4	7	0x0005f
5	5	6	0x0000a
5	6	6	0x0002d
5	7	5	0x0000e
6	0	10	0x0017a
6	1	9	0x000bf
6	2	8	0x00097
6	3	7	0x0003d
6	4	7	0x0007e
6	5	6	0x00032
6	6	5	0x0001b
6	7	4	0x00006
7	0	10	0x0017b
7	1	9	0x00177
7	2	8	0x0009f
7	3	7	0x0003f
7	4	6	0x0000b
7	5	5	0x00006
7	6	4	0x00004
7	7	4	0x0000e

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Table A.16 — hcod2D_NRG_DF_ZZ_09

Idx0	Idx1	DF/FP	
		length	codeword
0	0	5	0x000006
0	1	5	0x000010
0	2	6	0x000032
0	3	7	0x000068
0	4	8	0x0000d6
0	5	8	0x000066
0	6	10	0x0002fe
0	7	10	0x0002de
0	8	11	0x00077e
0	9	12	0x000efe
1	0	5	0x000011
1	1	4	0x000002
1	2	5	0x000012
1	3	6	0x000036
1	4	7	0x00006a
1	5	7	0x000026
1	6	8	0x00004e
1	7	8	0x00006a
1	8	9	0x000166
1	9	11	0x00037e
2	0	6	0x000037
2	1	5	0x00000e
2	2	5	0x00000a
2	3	6	0x00001e
2	4	7	0x000034
2	5	8	0x0000e0
2	6	8	0x0000e2
2	7	9	0x000167
2	8	10	0x0003bc
2	9	9	0x0000ca
3	0	7	0x000072
3	1	6	0x000033
3	2	6	0x000018
3	3	7	0x00005c
3	4	7	0x000008
3	5	7	0x00000e
3	6	8	0x00006e
3	7	9	0x0000de
3	8	9	0x0001da
3	9	9	0x00016e
4	0	8	0x0000e1
4	1	7	0x00003e
4	2	7	0x00001c
4	3	7	0x000006
4	4	7	0x000004
4	5	8	0x000064
4	6	9	0x0001db
4	7	8	0x0000b2
4	8	8	0x000067
4	9	8	0x00006b
5	0	9	0x0001c6
5	1	7	0x00001d
5	2	7	0x000007
5	3	8	0x0000ee
5	4	8	0x0000b6
5	5	8	0x0000ec

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Table A.16 *(continued)*

5	6	7	0x00003f
5	7	8	0x0000bc
5	8	7	0x00000a
5	9	7	0x000009
6	0	10	0x0002ff
6	1	9	0x0001c7
6	2	8	0x00004f
6	3	8	0x00001e
6	4	8	0x0000bd
6	5	7	0x00001e
6	6	8	0x0000d7
6	7	7	0x000036
6	8	7	0x000073
6	9	6	0x000026
7	0	10	0x0001be
7	1	9	0x0000cb
7	2	10	0x0003bd
7	3	8	0x00003e
7	4	7	0x00000b
7	5	7	0x000005
7	6	7	0x000069
7	7	6	0x000027
7	8	6	0x00003a
7	9	5	0x000008
8	0	11	0x00037f
8	1	10	0x0002df
8	2	9	0x00017e
8	3	8	0x0000ba
8	4	8	0x0000be
8	5	7	0x000058
8	6	6	0x000006
8	7	5	0x000000
8	8	5	0x000018
8	9	5	0x00001e
9	0	12	0x000eff
9	1	10	0x0003be
9	2	8	0x00003f
9	3	8	0x00001f
9	4	8	0x0000bb
9	5	7	0x00005a
9	6	6	0x000012
9	7	5	0x00000b
9	8	5	0x00001f
9	9	4	0x00000a

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Table A.17 — hcod2D_NRG_DT_ZZ_03

Idx0	Idx1	DT/FP	
		length	codeword
0	0	2	0x000
0	1	3	0x006
0	2	3	0x002
0	3	4	0x00e
1	0	3	0x004
1	1	4	0x006
1	2	5	0x00e
1	3	6	0x03e
2	0	6	0x03f
2	1	7	0x03e
2	2	7	0x03c
2	3	5	0x01e
3	0	8	0x07a
3	1	8	0x07b
3	2	7	0x03f
3	3	3	0x005

Table A.18 — hcod2D_NRG_DT_ZZ_06

Idx0	Idx1	DT/FP	
		length	codeword
0	0	4	0x0000e
0	1	5	0x00012
0	2	8	0x000ba
0	3	10	0x0027e
0	4	14	0x03dae
0	5	17	0x1ed7e
0	6	17	0x1ed7f
1	0	3	0x00002
1	1	4	0x00002
1	2	7	0x0005e
1	3	9	0x00176
1	4	11	0x004fe
1	5	16	0x0f6be
1	6	7	0x0000e
2	0	4	0x00008
2	1	4	0x00000
2	2	7	0x0007e
2	3	9	0x00177
2	4	11	0x004ff
2	5	8	0x000b8
2	6	6	0x00006
3	0	5	0x00006
3	1	5	0x00007
3	2	7	0x0004e
3	3	9	0x0013e
3	4	9	0x001ec
3	5	7	0x0007a
3	6	5	0x00016
4	0	6	0x00026
4	1	7	0x0007f
4	2	9	0x001ee
4	3	11	0x007b6
4	4	8	0x000be
4	5	6	0x0003c

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Table A.18 *(continued)*

4	6	4	0x0000a
5	0	7	0x0000f
5	1	8	0x000bf
5	2	12	0x00f6a
5	3	11	0x007b4
5	4	8	0x000b9
5	5	6	0x0003e
5	6	3	0x00003
6	0	9	0x001ef
6	1	15	0x07b5e
6	2	13	0x01ed6
6	3	11	0x007b7
6	4	8	0x0009e
6	5	5	0x00002
6	6	3	0x00006

Table A.19 — hcod2D_NRG_DT_ZZ_09

Idx0	Idx1	DT/FP	
		length	codeword
0	0	4	0x00004
0	1	5	0x0000a
0	2	8	0x000f6
0	3	10	0x0032e
0	4	11	0x002de
0	5	12	0x0035c
0	6	18	0x0d77c
0	7	18	0x0d77d
0	8	18	0x0d77e
0	9	14	0x032fa
1	0	4	0x0000a
1	1	4	0x00002
1	2	7	0x00066
1	3	9	0x000fe
1	4	11	0x001be
1	5	12	0x0037e
1	6	14	0x00d76
1	7	14	0x032fe
1	8	18	0x0d77f
1	9	8	0x0007a
2	0	5	0x0001a
2	1	5	0x00016
2	2	7	0x00064
2	3	9	0x001ea
2	4	10	0x0016e
2	5	11	0x0035e
2	6	12	0x0035e
2	7	14	0x032fb
2	8	8	0x0005e
2	9	7	0x0003c
3	0	6	0x0003c
3	1	5	0x00002
3	2	7	0x0005e
3	3	8	0x0005a
3	4	9	0x0006e
3	5	11	0x0065e
3	6	13	0x0197e
3	7	9	0x001ee
3	8	7	0x0002c
3	9	6	0x00018

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Table A.19 *(continued)*

4	0	6	0x00030
4	1	6	0x00036
4	2	7	0x00034
4	3	8	0x000f4
4	4	9	0x000f6
4	5	11	0x002df
4	6	10	0x003d6
4	7	8	0x0005f
4	8	7	0x0003e
4	9	6	0x0002e
5	0	6	0x0000c
5	1	6	0x0000e
5	2	7	0x00032
5	3	8	0x00036
5	4	10	0x000de
5	5	10	0x000d6
5	6	9	0x001ef
5	7	7	0x00033
5	8	7	0x0005f
5	9	6	0x00037
6	0	7	0x00036
6	1	6	0x00006
6	2	8	0x000ca
6	3	9	0x000ff
6	4	13	0x0197c
6	5	11	0x003de
6	6	8	0x00034
6	7	7	0x0000e
6	8	6	0x0000f
6	9	5	0x0000e
7	0	7	0x00037
7	1	7	0x0002e
7	2	9	0x00196
7	3	13	0x006ba
7	4	12	0x0037f
7	5	10	0x001ee
7	6	9	0x000d6
7	7	7	0x0000f
7	8	6	0x00031
7	9	4	0x00000
8	0	8	0x0006a
8	1	8	0x0007e
8	2	16	0x035de
8	3	13	0x00f7e
8	4	12	0x007be
8	5	10	0x001ae
8	6	9	0x0006a
8	7	8	0x000ce
8	8	6	0x0003e
8	9	4	0x0000e
9	0	9	0x000b6
9	1	15	0x01aee
9	2	13	0x00f7f
9	3	12	0x0035f
9	4	14	0x032ff
9	5	11	0x0035f
9	6	10	0x003d7
9	7	8	0x000cf
9	8	6	0x0003f
9	9	3	0x00004

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