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**Information technology — MPEG  
audio technologies —**

Part 2:

**Spatial Audio Object Coding (SAOC)**

**AMENDMENT 3: Dialogue enhancement**

*Technologies de l'information — Technologies audio MPEG —*

*Partie 2: Codage d'objet audio spatial (SAOC)*

*AMENDEMENT 3: Rehaussement des dialogues*

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The committee responsible for this document is ISO/IEC JTC 1, *Information technology*, Subcommittee SC 29, *Coding of audio, picture, multimedia and hypermedia information*.

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# Information technology — MPEG audio technologies —

## Part 2: Spatial Audio Object Coding (SAOC)

### AMENDMENT 3: Dialogue enhancement

Add Clause 12, Spatial Audio Object Coding — Dialogue Enhancement (SAOC-DE):

#### 12 Spatial Audio Object Coding — Dialogue Enhancement

##### 12.1 Introduction

This Clause specifies the SAOC Dialogue Enhancement (SAOC-DE) profile. The SAOC-DE decoder processing and bitstream syntax are defined according Clauses 1 to 9 with the following modifications.

##### — Basic structure of the SAOC transcoder/decoder

Add in "[Table 2](#) — Operation modes of the SAOC" the following text:

**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

##### — SAOC Profiles and Levels

Add in "[Table 4](#) — SAOC Profiles and Levels" the following text:

**Table 4 — SAOC Profiles and Levels**

Profiles	Baseline profile				DE profile		LD profile		
	1	2	3	4	1	2	1	2	3
Levels									
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*)	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**)
PCU LP decoder	6.6	12.2	23.0	46.0	11.4	21.0	N/A	N/A	N/A

**Table 4** (continued)

Profiles	Baseline profile				DE profile		LD profile		
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***)
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

Add below “Table 4 – SAOC Profiles and Levels” the following text:

MPS transcoding support for baseline and LD profile if the number of output channels > 2

Replace below “Table 4 – SAOC Profiles and Levels” the following text:

The SAOC decoder type is defined by the four conditions:

- Profile: baseline profile or LD profile

by

The SAOC decoder type is defined by the four conditions:

- Profile: baseline, LD or DE profile

Replace in “5.5 SAOC Profiles and Levels”:

For all profiles and levels the following features are supported:

- Decoding to mono/stereo/binaural output

by

For baseline and low-delay profiles:

- Decoding to mono/stereo/binaural output. Transcoding to 5.1 is supported

For Dialogue enhancement 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

**12.2 Terms and definitions**

Add in “4.4 Variables”:

$N_{FGO}$  is the number of FGOs.

$D_{FGO}$  is the downmix sub-matrix for FGOs.

- $D_{BGO}$  is the downmix sub-matrix for BGOs.
- $m_{BGO}$  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.

Add in "4.5 Abbreviated terms":

- BGO** Background Object
- FGO** Foreground Object
- DE** Dialogue Enhancement

**12.3 Payloads for SAOC-DE**

The bitstream syntax of the SAOC-DE is not compatible with the Baseline and Low Delay profiles of SAOC. The following changes are applied for SAOC-DE profile in "6.1 Payloads for SAOC":

**Introduction of DE bitstream elements**

Replace in "Table 5 — Syntax of SAOCSpecificConfig()":

**Table 5 — Syntax of SAOCSpecificConfig()**

Syntax	No. of bits	Mnemonic
SAOCSpecificConfig() {		

by

**Table 5 — Syntax of SAOCDESpecificConfig()**

Syntax	No. of bits	Mnemonic
SAOCDESpecificConfig() {		

Replace in "Table 20 — Syntax of SAOCFrame()":

**Table 20 — Syntax of SAOCFrame()**

Syntax	No. of bits	Mnemonic
SAOCFrame() {		

by

**Table 20 — Syntax of SAOCDEFrame()**

Syntax	No. of bits	Mnemonic
SAOCDEFrame() {		

Replace in "Table 21 — SAOCFramingInfo()":

**Table 21 — Syntax of SAOCFramingInfo()**

Syntax	No. of bits	Mnemonic
SAOCFramingInfo() {		

by

**Table 21 — Syntax of SAOCDEFramingInfo()**

Syntax	No. of bits	Mnemonic
SAOCDEFramingInfo() {		

Replace in “Table 20 — Syntax of SAOCFrame()”:

**Table 20 — Syntax of SAOCFrame()**

Syntax	No. of bits	Mnemonic
SAOCFrame() { SAOCFramingInfo();		

by

**Table 20 — Syntax of SAOCDEFramingInfo()**

Syntax	No. of bits	Mnemonic
SAOCDEFramingInfo() { SAOCDEFramingInfo();		

**Introduction of SAOC version bitstream element**

Add in “Table 5 — Syntax of SAOCSpecificConfig()”:

SAOCDESpecificConfig() {		
<b>bsVersion;</b>	<b>4</b>	<b>uimsbf</b>
if ( bsVersion == 0 ) {		
<b>bsSamplingFrequencyIndex;</b>	<b>4</b>	<b>uimsbf</b>

Add in “Table 5 — Syntax of SAOCSpecificConfig()”:

SAOCExtensionConfig();		
}		
}		

Add in “Table 20 — Syntax of SAOCFrame()”:

SAOCDEFramingInfo() {		
if ( bsVersion == 0 ) {		
SAOCDEFramingInfo();		

Add in "Table 20 — Syntax of SAOCFrame()":

<pre> SAOCExtensionFrame(); } } </pre>
--

**Disabling SAOC Low Delay mode signalization**

Remove from "Table 5 — Syntax of SAOCSpecificConfig()":

<b>bsLowDelayMode;</b>	<b>1</b>	<b>uimsbf</b>
------------------------	----------	---------------

Replace in "Table 5 — Syntax of SAOCSpecificConfig()":

<pre> if ( bsLowDelayMode == 0 ) { <b>bsFrameLength;</b> } else { <b>bsFrameLength;</b> } </pre>	<b>7</b>	<b>uimsbf</b>
	<b>5</b>	<b>uimsbf</b>

by

<b>bsFrameLength;</b>	<b>7</b>	<b>uimsbf</b>
-----------------------	----------	---------------

Replace in "Table 21 — SAOCFramingInfo()":

<pre> If ( bsLowDelayMode == 0 ) { <b>bsNumParamSets;</b> } else { <b>bsNumParamSets;</b> } </pre>	<b>3</b>	<b>uimsbf</b>
	<b>1</b>	<b>uimsbf</b>

by

<b>bsNumParamSets;</b>	<b>3</b>	<b>uimsbf</b>
------------------------	----------	---------------

**Disabling absolute energy information transport**

Remove from "Table 5 — Syntax of SAOCSpecificConfig()":

<b>bsTransmitAbsNrg;</b>	<b>1</b>	<b>uimsbf</b>
--------------------------	----------	---------------

Remove from “Table 20 — Syntax of SAOCFrame()”:

```

if ( bsTransmitAbsNrg ) {
    idxNRG = EcDataSaoc(NRG, 0, numBands);
}
    
```

**Modification on object information transport**

Replace in “Table 5 — Syntax of SAOCSpecificConfig()”:

<b>bsNumObjects;</b>	<b>5</b>	<b>uimsbf</b>
----------------------	----------	---------------

by

<b>bsNumObjects;</b>	<b>3</b>	<b>uimsbf</b>
<b>bsNumFGOs;</b>	<b>3</b>	<b>uimsbf</b>

**Modification on downmix channel number signalization**

Replace in “Table 5 — Syntax of SAOCSpecificConfig()”:

<b>bsNumDmxChannels;</b>	<b>1</b>	<b>uimsbf</b>
--------------------------	----------	---------------

by

<b>bsNumDmxChannels;</b>	<b>3</b>	<b>uimsbf</b>
--------------------------	----------	---------------

**Dual mode configuration information transport**

Remove from “Table 5 — Syntax of SAOCSpecificConfig()”:

```

if ( bsNumDmxChannels == 1 ) {
bsTttDualMode;
    if (bsTttDualMode) {
bsTttBandsLow;
        bsTttBandsHigh = numBands;
    } else {
        bsTttBandsLow = numBands;
    }
}
    
```

**Disabling post downmix gain information transport**

Remove from “Table 5 — Syntax of SAOCSpecificConfig()”:

<b>bsPdgFlag;</b>	<b>1</b>	<b>uimsbf</b>
-------------------	----------	---------------

Remove from “Table 20 — Syntax of SAOCFrame()”:

```

if ( bsPdgFlag == 1 ) {
    for ( i=0; i<bsNumDmxChannels + 1; i++) {
        idxPDG[i] = EcDataSaoc(PDG, i, numBands);
    }
}

```

Note 1

**Modification on downmix information transport**

Replace in “Table 20 — Syntax of SAOCFrame()”:

```

idxDMG = EcDataSaoc(DMG, 0, bsNumObjects+1);
if ( bsNumDmxChannels == 1 ) {
    idxDCLD = EcDataSaoc(DCLD, 0, bsNumObjects+1);
}

```

by

```

for ( i=0; i<bsNumDmxChannels + 1; i++) {
    idxDMG[i] = EcDataSaoc(DMG, 0, bsNumObjects+1);
}

```

**Modification range control setting transport**

Add in “Table 5 —Syntax of SAOCSpecificConfig()” the following text:

<b>bsOneIOC;</b>	<b>1</b>	<b>uimsbf</b>
<b>bsDeLimitFlag;</b>	<b>1</b>	<b>uimsbf</b>
if ( bsDeLimitFlag == 1 ) {		
<b>bsDeLimitFgo;</b>	<b>4</b>	<b>uimsbf</b>
<b>bsDeLimitBgo;</b>	<b>4</b>	<b>uimsbf</b>
} else {		
bsDeLimitFgo = 0;		
bsDeLimitBgo = 0;		
}		

Add in "Table 20 — Syntax of SAOCFrame()" the following text:

<pre> idxDMG[i] = EcDataSaoc(DMG, 0, bsNumObjects+1); } if ( bsDeLimitFlag == 1 ) {     if ( bsIndependencyFlag == 1 ) {         bsDeLimitUpdate = 1;     } else { <b>sDeLimitUpdate;</b>     }     if ( bsDeLimitUpdate == 1 ) { <b>bsDeLimitFgo;</b> <b>bsDeLimitBgo;</b>     } } </pre>	<p><b>1</b></p> <p><b>4</b></p> <p><b>4</b></p>	<p><b>uimsbf</b></p> <p><b>uimsbf</b></p> <p><b>uimsbf</b></p>
--	---	--

Add in "Table 7 — Syntax of SAOCExtensionConfigData(0)":

<pre> SAOCExtensionConfigData(0) {     if ( bsDeLimitFlag == 1 ) { <b>bsDeLimitFgoEAO;</b> <b>bsDeLimitBgoEAO;</b>     } else {         bsDeLimitFgoEAO = 0;         bsDeLimitBgoEAO = 0;     } } </pre>	<p><b>4</b></p> <p><b>4</b></p>	<p><b>uimsbf</b></p> <p><b>uimsbf</b></p>
--	---------------------------------	---

Add in "Table 28 — Syntax of SAOCExtensionFrameData(0)":

<pre> SAOCExtensionFrameData(0) {     if ( bsDeLimitFlag == 1 ) {         if ( bsIndependencyFlag == 1 ) {             bsDeLimitEaoUpdate = 1;         } else { <b>bsDeLimitEaoUpdate;</b>         }         if ( bsDeLimitEaoUpdate == 1 ) { <b>bsDeLimitFgoEAO;</b> <b>bsDeLimitBgoEAO;</b>         }     } } </pre>	<p><b>1</b></p> <p><b>4</b></p> <p><b>4</b></p>	<p><b>uimsbf</b></p> <p><b>uimsbf</b></p> <p><b>uimsbf</b></p>
--	---	--

## 12.4 Definition of bitstream variables

Add in "6.2 Definition" the following text:

**bsVersion** Defines the version of the bitstream according to Table AMD3.1.

**Table — AMD3.1 — bsVersion**

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

Add in "6.2 Definition" the following text:

**bsNumFGOs** Defines the number of FGOs according to Table AMD3.2.

**Table — AMD3.2 — bsNumFGOs**

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

**bsNumDmxChannels** Defines the number of downmix channels.

**Table — AMD3.3 — bsNumDmxChannels**

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

**bsDeLimitFlag** Defines whether the values **bsDeLimitFgo**, **bsDeLimitFgoEAO**, **bsDeLimitBgo** and **bsDeLimitBgoEAO** are transmitted in the bitstream.

**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.

**bsDeLimitFgo** Defines the value representing the lowest acceptable modification boundary related to the FGO for the modification range control algorithm according to Table AMD3.4.

**Table — AMD3.4 — bsDeLimitFgo, bsDeLimitFgoEAO, bsDeLimitBgo and bsDeLimitBgoEAO parameters quantization table**

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

- bsDeLimitFgoEAO** Same as **bsDeLimitFgo** but for application only in strict EAO mode.
- bsDeLimitBgo** Defines the value representing the lowest acceptable modification boundary related to the BGO for the modification range control algorithm according to Table X.
- bsDeLimitBgoEAO** Same as **bsDeLimitBgo** but for application only in strict EAO mode.
- bsDeLimitUpdate** Defines whether the values **bsDeLimitFgo** and **bsDeLimitBgo** are updated. More precisely, **bsDeLimitUpdate** == 1 means that the values **bsDeLimitFgo** and **bsDeLimitBgo** 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, whereas **bsDeLimitEaoUpdate** == 0 means that the previously transmitted values are kept.

Add in "6.2 Definition" the following text:

**Table — AMD3.5 — bsPresetMatrixType**

bsPresetMatrixType	Meaning
0	Mono playback system
1	Stereo playback system
2	5.0 playback system
3	3.0 playback system

## 12.5 Signals and parameters

### Input downmix signal

Add in "7.5.2 Input signal" the following text:

$$\mathbf{X} = \mathbf{x}^{n,k} = \begin{pmatrix} x_0 \\ \dots \\ x_M \end{pmatrix} \quad \text{for SAOC-DE downmix channel configurations,}$$

$$\mathbf{X} = \mathbf{x}^{n,k} = \begin{pmatrix} l_0 \\ r_0 \end{pmatrix} \quad \text{for stereo downmix,}$$

### Rendering matrix

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

Add in “7.5.4 Rendering matrix” the following text:

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

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

determined as

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

where

$$\begin{aligned} m_{FGO} &= m_G \text{ and } m_{BGO} = 1, & \text{if } m_G \leq 1, \\ m_{FGO} &= 1 \text{ and } m_{BGO} = m_G^{-1} & \text{if } m_G > 1. \end{aligned}$$

### Downmix matrix

Add in “7.5.5 Downmix matrix” the following text:

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

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

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

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

The downmix matrix has the following structure

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

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

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

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

### Post(processing) of downmix

Add in “Signals and parameters” the following text:

#### 7.4.3 Post(processing) downmix compensation

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

$$\mathbf{W}_{PDG} = \begin{pmatrix} PDG_1 & \dots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \dots & PDG_M \end{pmatrix}, \quad \text{for SAOC-DE profile,}$$

Add in “Signals and parameters” the following text:

**7.4.X Post(processed) re-application**

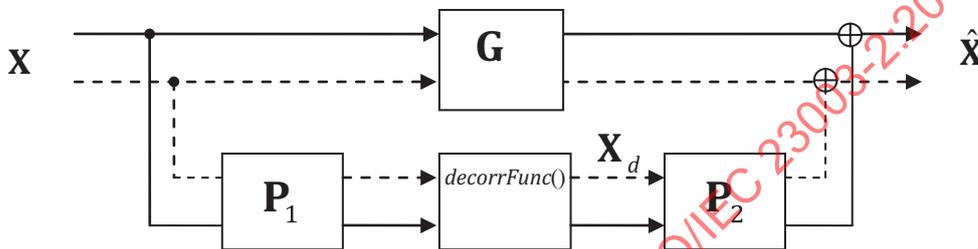
If the post(processed) downmix compensation is applied (**bsPdgFlag** == 1) for the SAOC-DE profile, the following modification should be taken after the SAOC processing

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

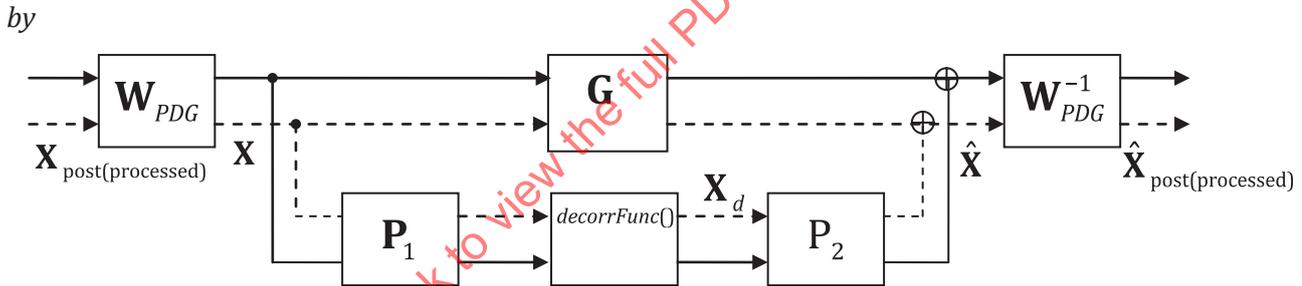
where

$$W_{PDG}^{-1} = \begin{pmatrix} 1 & \dots & 0 \\ \max(PDG_1, \epsilon) & \dots & \vdots \\ \vdots & \ddots & \vdots \\ 0 & \dots & \frac{1}{\max(PDG_M, \epsilon)} \end{pmatrix}.$$

Replace in "SAOC transcoding/decoding modes" the following figure:



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



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

**12.6 Decoding mode for SAOC-DE**

The parametric processing algorithm supporting up to 3-channel downmix configurations is specified as follows.

Add in “7.7.2 Downmix processor” the following text:

### 7.7.2.7 SAOC-DE “x-y-y” processing mode

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

$$\mathbf{G} = \mathbf{M}_{\text{ren}} \mathbf{E} \mathbf{D}^* \mathbf{J}, \quad \mathbf{P}_1 = \mathbf{0}, \mathbf{P}_2 = \mathbf{0}.$$

where  $\mathbf{J} \approx (\mathbf{D} \mathbf{E} \mathbf{D}^*)^{-1}$ . The matrix  $\mathbf{J}$  of size  $M \times M$  is defined as

$$\mathbf{J} = \mathbf{U} \mathbf{\Lambda}^{\text{inv}} \mathbf{U}^*.$$

Here the singular vector  $\mathbf{U}$  of the matrix product  $\mathbf{D} \mathbf{E} \mathbf{D}^*$  is obtained using the following characteristic equation

$$\mathbf{U} \mathbf{A} \mathbf{U}^* = \mathbf{D} \mathbf{E} \mathbf{D}^*.$$

The regularized inverse  $\mathbf{\Lambda}^{\text{inv}}$  of the diagonal singular value matrix  $\mathbf{\Lambda}$  is computed as

$$\lambda_{i,j}^{\text{inv}} = \begin{cases} \frac{1}{\lambda_{i,j}}, & \text{if } i = j \text{ and } \lambda_{i,j} \geq T_{\text{reg}}^{\Lambda}, \\ 0, & \text{otherwise,} \end{cases}$$

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

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

The decorrelator signal path is disabled  $\mathbf{X}_d = \mathbf{0}$ .

## 12.7 EAO processing for SAOC-DE

The SAOC architecture supporting EAO for up to 3-channel downmix configurations is specified as follows.

Add (after “7.8 EAO processing”) the following text:

### 7.X EAO processing for SAOC-DE processing modes

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  $m_{\text{BGO}}$ ,  $m_{\text{FGO}}$  as

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

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

The matrix  $\mathbf{R}_{\text{eao}}$  is defined as  $\mathbf{R}_{\text{eao}} = (\mathbf{O} \quad \mathbf{I})$ , where the elements of sub-matrix  $\mathbf{O}$  of size  $N_{\text{EAO}} \times N - N_{\text{EAO}}$  is defined as  $O_{i,j} = 0$ , and sub-matrix  $\mathbf{I}$  of size  $N_{\text{EAO}} \times N_{\text{EAO}}$  is defined as  $I_{i,j} = 0$ , if  $i \neq j$  and  $I_{i,j} = 1$ , if  $i = j$ .

## 12.8 Modification range control for SAOC-DE

The output modification range control for SAOC-DE is specified as follows.

Add (after “7.9 DCU processing”) the following text:

### 7. Modification range control for SAOC-DE processing modes

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