

Appendix 3: Dominance - Additional Details

The primary sources of information regarding the dominance transformation appear to be [50] and [52]; the treatment in these publications is however rather sparse. In support of the discussions of dominance in sections 5.3.3 and 6.5.3 of this thesis, some further details are presented in this appendix.

The transformed W signal

$$W_2 = \frac{1}{2}(I + I^{-1})W_1 + \frac{1}{\sqrt{8}}(I - I^{-1})X_1 \quad (\text{A3.1})$$

Substituting in expressions for W_1 and X_1 in terms of the encoded amplitude and direction of a source

$$\begin{aligned} W_2 &= \frac{1}{2}(I + I^{-1})\frac{1}{\sqrt{2}}A_1 + \frac{1}{\sqrt{8}}(I - I^{-1})A_1 \cos(\mathbf{q}_1) \cos(\mathbf{f}_1) \\ &= \frac{1}{\sqrt{8}}(I + I^{-1})A_1 + \frac{1}{\sqrt{8}}(I - I^{-1})\cos(\mathbf{q}_1) \cos(\mathbf{f}_1)A_1 \\ &= \frac{1}{\sqrt{8}}\left[(I + I^{-1}) + (I - I^{-1})\cos(\mathbf{q}_1) \cos(\mathbf{f}_1)\right]A_1 \\ &= \frac{1}{\sqrt{8}}\left[I(1 + \cos(\mathbf{q}_1) \cos(\mathbf{f}_1)) + I^{-1}(1 - \cos(\mathbf{q}_1) \cos(\mathbf{f}_1))\right]A_1 \end{aligned} \quad (\text{A3.2})$$

Therefore

$$\begin{aligned} \frac{1}{\sqrt{2}}A_2 &= \frac{1}{\sqrt{8}}\left[I(1 + \cos(\mathbf{q}_1) \cos(\mathbf{f}_1)) + I^{-1}(1 - \cos(\mathbf{q}_1) \cos(\mathbf{f}_1))\right]A_1 \\ &= \frac{1}{\sqrt{2}}\frac{1}{2}\left[I(1 + \cos(\mathbf{q}_1) \cos(\mathbf{f}_1)) + I^{-1}(1 - \cos(\mathbf{q}_1) \cos(\mathbf{f}_1))\right]A_1 \\ A_2 &= \frac{1}{2}\left[I(1 + \cos(\mathbf{q}_1) \cos(\mathbf{f}_1)) + I^{-1}(1 - \cos(\mathbf{q}_1) \cos(\mathbf{f}_1))\right]A_1 \end{aligned} \quad (\text{A3.3})$$

Now

$$X_2 = \frac{1}{2}(I + I^{-1})X_1 + \frac{1}{\sqrt{2}}(I - I^{-1})W_1 \quad (\text{A3.4})$$

Substituting in for W_1 and X_1

$$\begin{aligned} X_2 &= \frac{1}{2}(I + I^{-1})A_1 \cos(q_1) \cos(f_1) + \frac{1}{\sqrt{2}}(I - I^{-1})\frac{1}{\sqrt{2}}A_1 \\ &= \frac{1}{2}(I + I^{-1})\cos(q_1) \cos(f_1)A_1 + \frac{1}{2}(I - I^{-1})A_1 \\ &= \frac{1}{2}[(I + I^{-1})\cos(q_1) \cos(f_1) + (I - I^{-1})]A_1 \\ &= \frac{1}{2}[I(1 + \cos(q_1) \cos(f_1)) + I^{-1}(\cos(q_1) \cos(f_1) - 1)]A_1 \end{aligned} \quad (\text{A3.5})$$

Therefore

$$A_2 \cos(q_2) \cos(f_2) = \frac{1}{2}[I(1 + \cos(q_1) \cos(f_1)) + I^{-1}(\cos(q_1) \cos(f_1) - 1)]A_1 \quad (\text{A3.6})$$

Substituting in for A_2 we obtain

$$\begin{aligned} &\frac{1}{2}[I(1 + \cos(q_1) \cos(f_1)) + I^{-1}(1 - \cos(q_1) \cos(f_1))]A_1 \cos(q_2) \cos(f_2) \\ &= \frac{1}{2}[I(1 + \cos(q_1) \cos(f_1)) + I^{-1}(\cos(q_1) \cos(f_1) - 1)]A_1 \\ &[I(1 + \cos(q_1) \cos(f_1)) + I^{-1}(1 - \cos(q_1) \cos(f_1))] \cos(q_2) \cos(f_2) \\ &= [I(1 + \cos(q_1) \cos(f_1)) + I^{-1}(\cos(q_1) \cos(f_1) - 1)] \end{aligned} \quad (\text{A3.7})$$

Which may be rearranged to give

$$\begin{aligned}
\cos(q_2)\cos(f_2) &= \frac{I(1 + \cos(q_1)\cos(f_1)) + I^{-1}(\cos(q_1)\cos(f_1) - 1)}{I(1 + \cos(q_1)\cos(f_1)) + I^{-1}(1 - \cos(q_1)\cos(f_1))} \\
&= \frac{I^2(1 + \cos(q_1)\cos(f_1)) + \cos(q_1)\cos(f_1) - 1}{I^2(1 + \cos(q_1)\cos(f_1)) + 1 - \cos(q_1)\cos(f_1)} \\
&= \frac{I^2 + I^2\cos(q_1)\cos(f_1) + \cos(q_1)\cos(f_1) - 1}{I^2 + I^2\cos(q_1)\cos(f_1) + 1 - \cos(q_1)\cos(f_1)} \\
&= \frac{I^2 - 1 + (I^2 + 1)\cos(q_1)\cos(f_1)}{I^2 + 1 + (I^2 - 1)\cos(q_1)\cos(f_1)}
\end{aligned} \tag{A3.8}$$

Now Y is unchanged by the forward dominance transformation:

$$Y_2 = Y_1 \tag{A3.9}$$

Therefore

$$A_2 \sin(q_2)\cos(f_2) = A_1 \sin(q_1)\cos(f_1) \tag{A3.10}$$

Substituting in for A_2 we obtain

$$\begin{aligned}
\frac{1}{2} [I(1 + \cos(q_1)\cos(f_1)) + I^{-1}(1 - \cos(q_1)\cos(f_1))] A_1 \sin(q_2)\cos(f_2) \\
&= A_1 \sin(q_1)\cos(f_1) \\
\frac{1}{2} [I(1 + \cos(q_1)\cos(f_1)) + I^{-1}(1 - \cos(q_1)\cos(f_1))] \sin(q_2)\cos(f_2) \\
&= \sin(q_1)\cos(f_1)
\end{aligned} \tag{A3.11}$$

Rearranging gives

$$\begin{aligned}
\sin(q_2)\cos(f_2) &= \frac{2\sin(q_1)\cos(f_1)}{I(1 + \cos(q_1)\cos(f_1)) + I^{-1}(1 - \cos(q_1)\cos(f_1))} \\
&= \frac{2I\sin(q_1)\cos(f_1)}{I^2(1 + \cos(q_1)\cos(f_1)) + 1 - \cos(q_1)\cos(f_1)} \\
&= \frac{2I\sin(q_1)\cos(f_1)}{(I^2 + 1) + (I^2 - 1)\cos(q_1)\cos(f_1)}
\end{aligned} \tag{A3.12}$$

Similarly, given that

$$Z_2 = Z_1 \tag{A3.13}$$

by substitution and rearrangement we obtain

$$\sin(f_2) = \frac{2I \sin(f_1)}{(I^2 + 1) + (I^2 - 1)\cos(q_1)\cos(f_1)} \tag{A3.14}$$

Appendix 4: Additional Material to Support Section 6.2*A4.1: Transformation Matrices*

$$\mathbf{M}_{FU} = \begin{bmatrix} c^- & 0 & -c^+ \\ 0 & 1 & 0 \\ c^+ & 0 & c^- \end{bmatrix}$$

$$\mathbf{M}_{FU}^{-1} = \begin{bmatrix} c^- & 0 & c^+ \\ 0 & 1 & 0 \\ -c^+ & 0 & c^- \end{bmatrix}$$

$$\mathbf{M}_{FD} = \begin{bmatrix} -c^- & 0 & -c^+ \\ 0 & 1 & 0 \\ c^+ & 0 & -c^- \end{bmatrix}$$

$$\mathbf{M}_{FD}^{-1} = \begin{bmatrix} -c^- & 0 & c^+ \\ 0 & 1 & 0 \\ -c^+ & 0 & -c^- \end{bmatrix}$$

$$\mathbf{M}_{BU} = \begin{bmatrix} c^- & 0 & c^+ \\ 0 & 1 & 0 \\ -c^+ & 0 & c^- \end{bmatrix}$$

$$\mathbf{M}_{BU}^{-1} = \begin{bmatrix} c^- & 0 & -c^+ \\ 0 & 1 & 0 \\ c^+ & 0 & c^- \end{bmatrix}$$

$$\mathbf{M}_{BD} = \begin{bmatrix} -c^- & 0 & c^+ \\ 0 & 1 & 0 \\ -c^+ & 0 & -c^- \end{bmatrix}$$

$$\mathbf{M}_{BD}^{-1} = \begin{bmatrix} -c^- & 0 & -c^+ \\ 0 & 1 & 0 \\ c^+ & 0 & -c^- \end{bmatrix}$$

$$\mathbf{M}_{LF} = \begin{bmatrix} 0 & 0 & -1 \\ -c^+ & c^- & 0 \\ c^- & c^+ & 0 \end{bmatrix}$$

$$\mathbf{M}_{LF}^{-1} = \begin{bmatrix} 0 & -c^+ & c^- \\ 0 & c^- & c^+ \\ -1 & 0 & 0 \end{bmatrix}$$

$$\mathbf{M}_{LB} = \begin{bmatrix} 0 & 0 & 1 \\ c^+ & c^- & 0 \\ -c^- & c^+ & 0 \end{bmatrix}$$

$$\mathbf{M}_{LB}^{-1} = \begin{bmatrix} 0 & c^+ & -c^- \\ 0 & c^- & c^+ \\ 1 & 0 & 0 \end{bmatrix}$$

$$\mathbf{M}_{RF} = \begin{bmatrix} 0 & 0 & -1 \\ c^+ & c^- & 0 \\ c^- & -c^+ & 0 \end{bmatrix}$$

$$\mathbf{M}_{RF}^{-1} = \begin{bmatrix} 0 & c^+ & c^- \\ 0 & c^- & -c^+ \\ -1 & 0 & 0 \end{bmatrix}$$

$$\mathbf{M}_{RB} = \begin{bmatrix} 0 & 0 & 1 \\ -c^+ & c^- & 0 \\ -c^- & -c^+ & 0 \end{bmatrix}$$

$$\mathbf{M}_{RB}^{-1} = \begin{bmatrix} 0 & -c^+ & -c^- \\ 0 & c^- & -c^+ \\ 1 & 0 & 0 \end{bmatrix}$$

$$\begin{aligned}
 \mathbf{M}_{UL} &= \begin{bmatrix} 1 & 0 & 0 \\ 0 & c^+ & -c^- \\ 0 & c^- & c^+ \end{bmatrix} & \mathbf{M}_{UR} &= \begin{bmatrix} 1 & 0 & 0 \\ 0 & c^+ & c^- \\ 0 & -c^- & c^+ \end{bmatrix} \\
 \mathbf{M}_{UL}^{-1} &= \begin{bmatrix} 1 & 0 & 0 \\ 0 & c^+ & c^- \\ 0 & -c^- & c^+ \end{bmatrix} & \mathbf{M}_{UR}^{-1} &= \begin{bmatrix} 1 & 0 & 0 \\ 0 & c^+ & -c^- \\ 0 & c^- & c^+ \end{bmatrix} \\
 \\ \\
 \mathbf{M}_{DL} &= \begin{bmatrix} 1 & 0 & 0 \\ 0 & -c^+ & -c^- \\ 0 & c^- & -c^+ \end{bmatrix} & \mathbf{M}_{DR} &= \begin{bmatrix} 1 & 0 & 0 \\ 0 & -c^+ & c^- \\ 0 & -c^- & -c^+ \end{bmatrix} \\
 \mathbf{M}_{DL}^{-1} &= \begin{bmatrix} 1 & 0 & 0 \\ 0 & -c^+ & c^- \\ 0 & -c^- & -c^+ \end{bmatrix} & \mathbf{M}_{DR}^{-1} &= \begin{bmatrix} 1 & 0 & 0 \\ 0 & -c^+ & -c^- \\ 0 & c^- & -c^+ \end{bmatrix}
 \end{aligned}$$

A4.2: Integrals

$f(f')$	$\int_{-p/2}^{p/2} f(f') df'$
$e^{jkr \sin(f')} \cos(f')$	$2j_0(kr)$
$e^{jkr \sin(f')} \sin(f') \cos(f')$	$j2j_1(kr)$
$e^{jkr \sin(f')} \sin^2(f') \cos(f')$	$\frac{2}{3}[j_0(kr) - 2j_2(kr)]$
$e^{jkr \sin(f')} \cos^3(f')$	$\frac{4}{3}[j_0(kr) + j_2(kr)]$
$e^{jkr \sin(f')} \sin(f') \cos^3(f')$	$j\frac{4}{5}[j_1(kr) + j_3(kr)]$
$e^{jkr \sin(f')} \sin^3(f') \cos(f')$	$j\frac{2}{5}[3j_1(kr) - 2j_3(kr)]$
$e^{jkr \sin(f')} \sin^2(f') \cos^3(f')$	$\frac{4}{105}[7j_0(kr) - 5j_2(kr) - 12j_4(kr)]$
$e^{jkr \sin(f')} \sin^4(f') \cos(f')$	$\frac{2}{35}[7j_0(kr) - 20j_2(kr) + 8j_4(kr)]$

Table A4.1: Integrals which Arise in the Derivation of the A-B Matrix

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Note: AES = Audio Engineering Society;

JAES = Journal of the Audio Engineering Society;

JASA = Journal of the Acoustical Society of America.

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† This information is, at the time of writing, available via the WWW at http://www.york.ac.uk/inst/mustech/3d_audio/secondor.html