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An Introduction to Spatial Sound (6):

Ambisonic Encoding/Decoding Calculations:

Example 1(a):

Encode the following mono source M_1:

> **Azimuth = 45^o**
> **Elevation = 0^o**

Using:

W = input signal x 0.707
X = input signal x $cos(\varphi).cos(\theta)$
Y = input signal x $cos(\varphi).sin(\theta)$
Z = input signal x $sin(\varphi)$

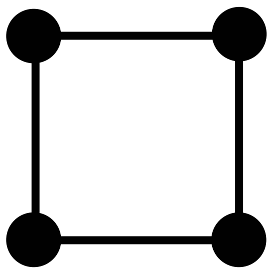
$W = M_1$ x 0.707
$X = M_1$ x cos(0).cos(45^o)
$Y = M_1$ x cos(0).sin(45^o)
$Z = M_1$ x sin(0)

Therefore:

$W = M_1$ x 0.707
$X = M_1$ x 0.707
$Y = M_1$ x 0.707
$Z = 0$

1(b) Decode M_1 with a cardioid speaker response for a square 4-speaker horizontal rig:

A cardioid response implies $d = 1$. Note that for a square 4-speaker horizontal rig the speakers are located as follows:



$S_1 = 45^o$
$S_2 = 135^o$
$S_3 = 225^o$
$S_4 = 315^o$

Using:

$g_w = \sqrt{2} = 1.414$
$g_x = cos(\varphi).cos(\theta)$
$g_y = cos(\varphi).sin(\theta)$
$g_z = sin(\varphi)$
$S_i = 0.5 \times [(2-d) \cdot g_w \cdot W + d \cdot (g_x \cdot X + g_y \cdot Y + g_z \cdot Z)]$

Therefore:

$S_1 = 0.5 \times [1.414 \cdot W + \cos(45^o) \cdot X + \sin(45^o) \cdot Y]$
$S_2 = 0.5 \times [1.414 \cdot W + \cos(135^o) \cdot X + \sin(135^o) \cdot Y]$
$S_3 = 0.5 \times [1.414 \cdot W + \cos(225^o) \cdot X + \sin(225^o) \cdot Y]$
$S_4 = 0.5 \times [1.414 \cdot W + \cos(315^o) \cdot X + \sin(315^o) \cdot Y]$

And so:

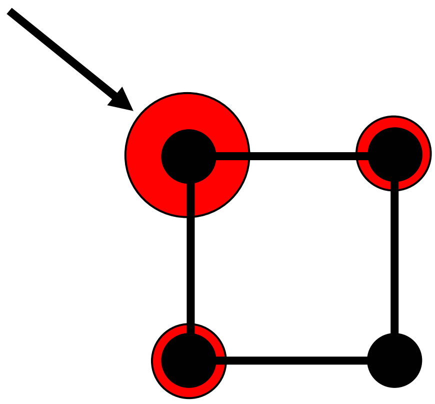
S_1 = 0.5 x [1.414·W + 0.707·X + 0.707·Y]
S_2 = 0.5 x [1.414·W - 0.707·X + 0.707·Y]
S_3 = 0.5 x [1.414·W - 0.707·X - 0.707·Y]
S_4 = 0.5 x [1.414·W + 0.707·X - 0.707·Y]

Notice the opposite polarity of the B-format gains.

Combining Encode and Decode Equations:

S_1 = 0.5 x [1.414·(M_1 x 0.707) + 0.707·(M_1 x 0.707) + 0.707·(M_1 x 0.707)]
S_2 = 0.5 x [1.414·(M_1 x 0.707) - 0.707·(M_1 x 0.707) + 0.707·(M_1 x 0.707)]
S_3 = 0.5 x [1.414·(M_1 x 0.707) - 0.707·(M_1 x 0.707) - 0.707·(M_1 x 0.707)]
S_4 = 0.5 x [1.414·(M_1 x 0.707) + 0.707·(M_1 x 0.707) - 0.707·(M_1 x 0.707)]

S_1 = 0.5 x [M_1 + 0.5·M_1 + 0.5·M_1]
S_2 = 0.5 x [M_1 - 0.5·M_1 + 0.5·M_1]
S_3 = 0.5 x [M_1 - 0.5·M_1 - 0.5·M_1]
S_4 = 0.5 x [M_1 + 0.5·M_1 - 0.5·M_1]



S_1 = 0.5·M_1 + 0.25·M_1 + 0.25·M_1
S_2 = 0.5·M_1 - 0.25·M_1 + 0.25·M_1
S_3 = 0.5·M_1 - 0.25·M_1 - 0.25·M_1
S_4 = 0.5·M_1 + 0.25·M_1 - 0.25·M_1

S_1 = M_1
S_2 = 0.5·M_1
S_3 = 0
S_4 = 0.5·M_1

2 - Encode and Decode source M_2 with a cardioid speaker response at position:
Azimuth = 90°
Elevation = 0°

Encode Using:

W = input signal x 0.707
X = input signal x $\cos(\varphi).\cos(\theta)$
Y = input signal x $\cos(\varphi).\sin(\theta)$
Z = input signal x $\sin(\varphi)$

W = M_2 x 0.707
X = M_2 x cos(0).cos(90°)
Y = M_2 x cos(0).sin(90°)
Z = M_2 x sin(0)

Therefore:

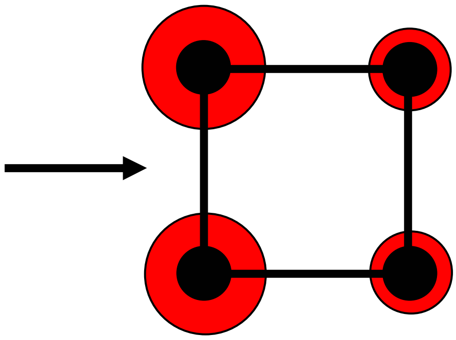
W = M_2 x 0.707
X = 0
Y = M_2
Z = 0

Combining Encode and Decode Equations:

S_1 = 0.5 x [1.414·(M_2 x 0.707) + 0.707·(0) + 0.707·(M_2)]
S_2 = 0.5 x [1.414·(M_2 x 0.707) - 0.707·(0) + 0.707·(M_2)]
S_3 = 0.5 x [1.414·(M_2 x 0.707) - 0.707·(0) - 0.707·(M_2)]
S_4 = 0.5 x [1.414·(M_2 x 0.707) + 0.707·(0) - 0.707·(M_2)]

Therefore:

$S_1 = 0.5 \times [1.414 \cdot (M_2 \times 0.707) + 0.707 \cdot (M_2)]$
$S_2 = 0.5 \times [1.414 \cdot (M_2 \times 0.707) + 0.707 \cdot (M_2)]$
$S_3 = 0.5 \times [1.414 \cdot (M_2 \times 0.707) - 0.707 \cdot (M_2)]$
$S_4 = 0.5 \times [1.414 \cdot (M_2 \times 0.707) - 0.707 \cdot (M_2)]$

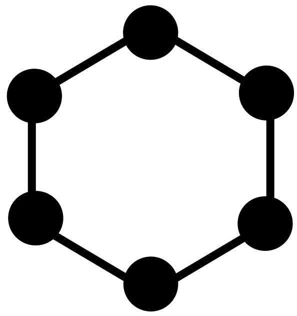


$S_1 = 0.8534 \cdot M_2$
$S_2 = 0.8534 \cdot M_2$
$S_3 = 0.1464 \cdot M_2$
$S_4 = 0.1464 \cdot M_2$

3 - Decode M_1 and M_2 for a hexagonal 6-speaker horizontal rig:

A cardioid response implies d = 1. Note that for a square 6-speaker hexagonal rig the speakers are located as follows:

$S_1 = 0^o$
$S_2 = 60^o$
$S_3 = 120^o$
$S_4 = 180^o$
$S_5 = 240^o$
$S_6 = 300^o$



Using:

$g_w = \sqrt{2} = 1.414$
$g_x = cos(\varphi).cos(\theta)$
$g_y = cos(\varphi).sin(\theta)$
$g_z = sin(\varphi)$
$S_i = 0.5 \times [(2-d) \cdot g_w \cdot W + d \cdot (g_x \cdot X + g_y \cdot Y + g_z \cdot Z)]$

Therefore:

$S_1 = 0.5 \times [1.414 \cdot W + \cos(0^o) \cdot X + \sin(0^o) \cdot Y]$
$S_2 = 0.5 \times [1.414 \cdot W + \cos(60^o) \cdot X + \sin(60^o) \cdot Y]$
$S_3 = 0.5 \times [1.414 \cdot W + \cos(120^o) \cdot X + \sin(120^o) \cdot Y]$
$S_4 = 0.5 \times [1.414 \cdot W + \cos(180^o) \cdot X + \sin(180^o) \cdot Y]$
$S_5 = 0.5 \times [1.414 \cdot W + \cos(240^o) \cdot X + \sin(240^o) \cdot Y]$
$S_6 = 0.5 \times [1.414 \cdot W + \cos(300^o) \cdot X + \sin(300^o) \cdot Y]$

And so:

$S_1 = 0.5 \times [1.414 \cdot W + X]$
$S_2 = 0.5 \times [1.414 \cdot W + 0.5 \cdot X + 0.866 \cdot Y]$
$S_3 = 0.5 \times [1.414 \cdot W - 0.5 \cdot X + 0.866 \cdot Y]$
$S_4 = 0.5 \times [1.414 \cdot W - X]$
$S_5 = 0.5 \times [1.414 \cdot W - 0.5 \cdot X - 0.866 \cdot Y]$
$S_6 = 0.5 \times [1.414 \cdot W + 0.5 \cdot X - 0.866 \cdot Y]$

For M_1:

$W = M_1 \times 0.707$
$X = M_1 \times 0.707$
$Y = M_1 \times 0.707$
$Z = 0$

Therefore:

$S_1 = 0.5 \text{ x } [1.414 \cdot (M_1 \text{ x } 0.707) + (M_1 \text{ x } 0.707)]$

$S_2 = 0.5 \text{ x } [1.414 \cdot (M_1 \text{ x } 0.707) + 0.5 \cdot (M_1 \text{ x } 0.707) + 0.866 \cdot (M_1 \text{ x } 0.707)]$

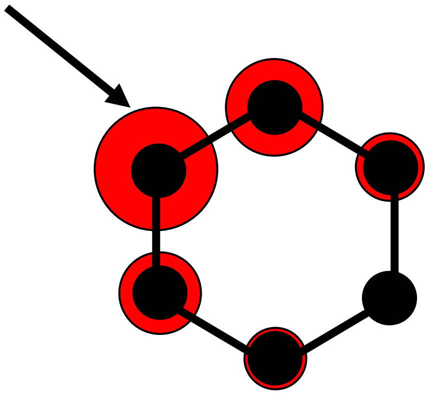
$S_3 = 0.5 \text{ x } [1.414 \cdot (M_1 \text{ x } 0.707) - 0.5 \cdot (M_1 \text{ x } 0.707) + 0.866 \cdot (M_1 \text{ x } 0.707)]$

$S_4 = 0.5 \text{ x } [1.414 \cdot (M_1 \text{ x } 0.707) - (M_1 \text{ x } 0.707)]$

$S_5 = 0.5 \text{ x } [1.414 \cdot (M_1 \text{ x } 0.707) - 0.5 \cdot (M_1 \text{ x } 0.707) – 0.866 \cdot (M_1 \text{ x } 0.707)]$

$S_6 = 0.5 \text{ x } [1.414 \cdot (M_1 \text{ x } 0.707) + 0.5 \cdot (M_1 \text{ x } 0.707) - 0.866 \cdot (M_1 \text{ x } 0.707)]$

$S_1 = 0.8534 \cdot M_1$
$S_2 = 0.9827 \cdot M_1$
$S_3 = 0.6292 \cdot M_1$
$S_4 = 0.1464 \cdot M_1$
$S_5 = 0.017 \cdot M_1$
$S_6 = 0.3705 \cdot M_1$



For M_2:

$W = M_2 \text{ x } 0.707$
$X = 0$
$Y = M_2$
$Z = 0$

Therefore:

$S_1 = 0.5 \text{ x } [1.414 \cdot (M_2 \text{ x } 0.707)]$

$S_2 = 0.5 \text{ x } [1.414 \cdot (M_2 \text{ x } 0.707) + 0.866 \cdot (M_2)]$

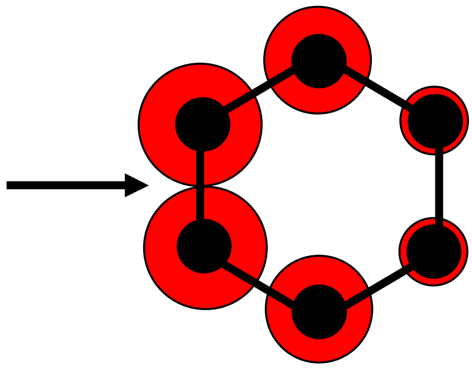
$S_3 = 0.5 \text{ x } [1.414 \cdot (M_2 \text{ x } 0.707) + 0.866 \cdot (M_2)]$

$S_4 = 0.5 \text{ x } [1.414 \cdot (M_2 \text{ x } 0.707)]$

$S_5 = 0.5 \text{ x } [1.414 \cdot (M_2 \text{ x } 0.707) - 0.866 \cdot (M_2)]$

$S_6 = 0.5 \text{ x } [1.414 \cdot (M_2 \text{ x } 0.707) - 0.866 \cdot (M_2)]$

$S_1 = 0.5 \cdot M_2$
$S_2 = 0.933 \cdot M_2$
$S_3 = 0.933 \cdot M_2$
$S_4 = 0.5 \cdot M_2$
$S_5 = 0.067 \cdot M_2$
$S_6 = 0.067 \cdot M_2$



4(a) Encode and Decode source M_3 with a cardioid speaker response at position:
Azimuth = 0°
Elevation = 0°

(a) Using:

W = input signal x 0.707
X = input signal x $cos(\varphi).cos(\theta)$
Y = input signal x $cos(\varphi).sin(\theta)$
Z = input signal x $sin(\varphi)$

$W = M_3 \text{ x } 0.707$
$X = M_3 \text{ x } \cos(0).\cos(0^o)$
$Y = M_3 \text{ x } \cos(0).\sin(0^o)$
$Z = M_3 \text{ x } \sin(0)$

Therefore:

$W = M_3 \text{ x } 0.707$
$X = M_3$
$Y = 0$
$Z = 0$

And so:

$S_1 = 0.5 \times [1.414\cdot(M_3 \times 0.707) + M_3]$

$S_2 = 0.5 \times [1.414\cdot(M_3 \times 0.707) + 0.5\cdot M_3]$

$S_3 = 0.5 \times [1.414\cdot(M_3 \times 0.707) - 0.5\cdot M_3]$

$S_4 = 0.5 \times [1.414\cdot(M_3 \times 0.707) - M_3]$

$S_5 = 0.5 \times [1.414\cdot(M_3 \times 0.707) - 0.5\cdot M_3]$

$S_6 = 0.5 \times [1.414\cdot(M_3 \times 0.707) + 0.5\cdot M_3]$

$S_1 = M_3$

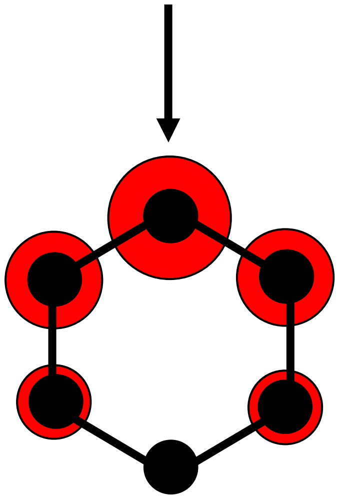
$S_2 = 0.75\cdot M_3$

$S_3 = 0.25\cdot M_3$

$S_4 = 0$

$S_5 = 0.25\cdot M_3$

$S_6 = 0.75\cdot M_3$



4(b) What would this sound like? Interpret your results.