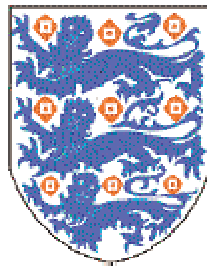


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# W-Panning and O-format: Tools for Object Spatialisation



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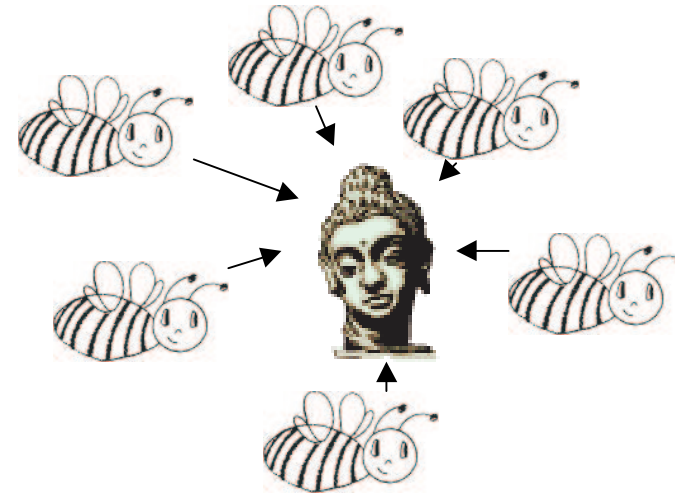
dylan zenprobe com  
[www.zenprobe.com/pub](http://www.zenprobe.com/pub)

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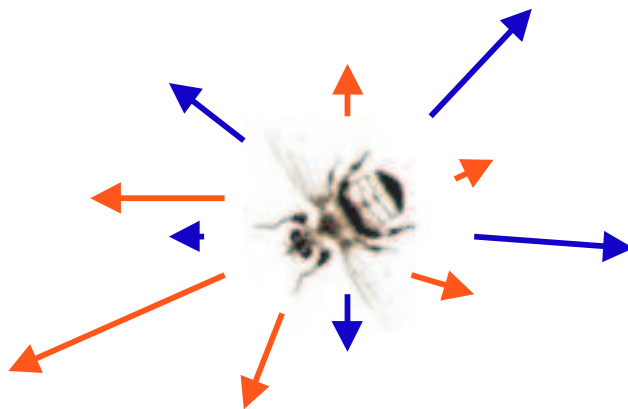
# Object Properties



- Objects have width.



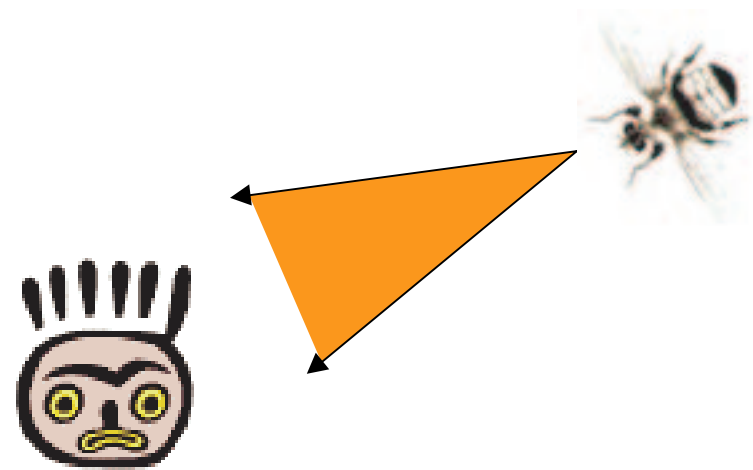
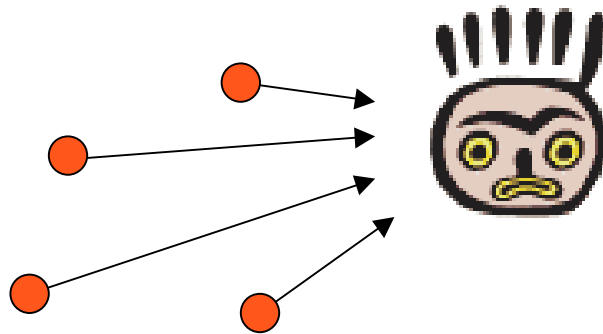
- Some objects are penetrable, eg a swarm.



- Objects have freq-dependent radiation patterns.

## Existing Methods

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### Width : Manybodies

- Simulate width using several points.
- Not smooth when penetrating object, because a point may come close.
- Extra processing required.

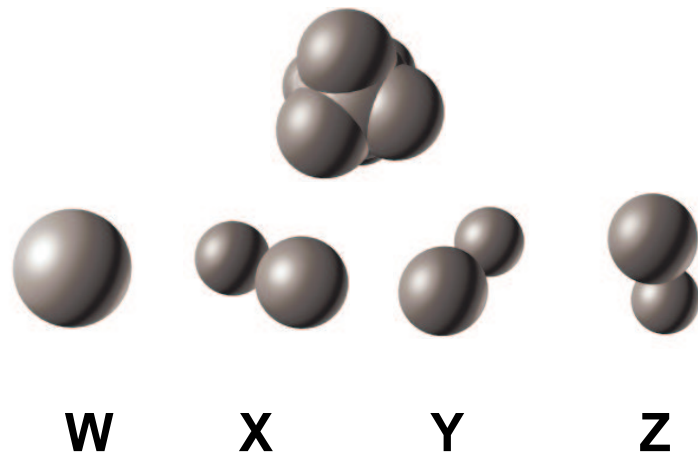
### Radiation : Soundcones

- Not freq-dependent.
- Need many to get frequency dependent distribution.

# Ambisonics : brief summary

## Encoding : Spherical harmonics

1<sup>st</sup> order is called *B-format*



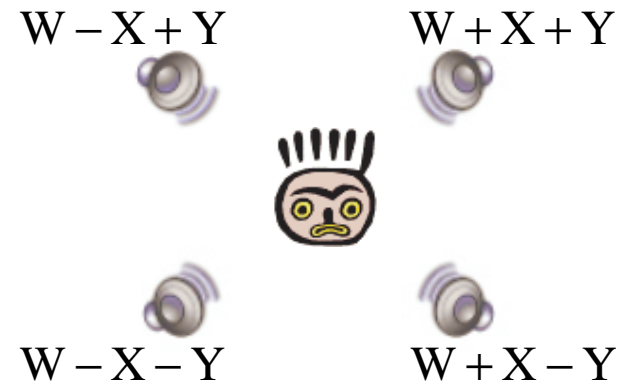
For a signal in one direction:

$$2W^2 = X^2 + Y^2 + Z^2$$

Easy soundfield rotation  
by rotating (X,Y,Z).

## Decoding for speaker arrays

Eg - simple 2D 4-speaker



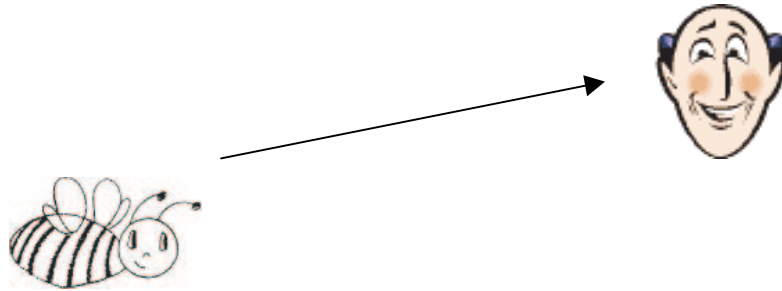
## Converting B-format to binaural

$$F_i = \int d\Omega Y_i(\theta, \phi) HRTF_L(\theta, \phi), \quad i = W, X, Y, Z$$

$$B_L = F_W(W) + F_X(X) + F_Y(Y) + F_Z(Z)$$

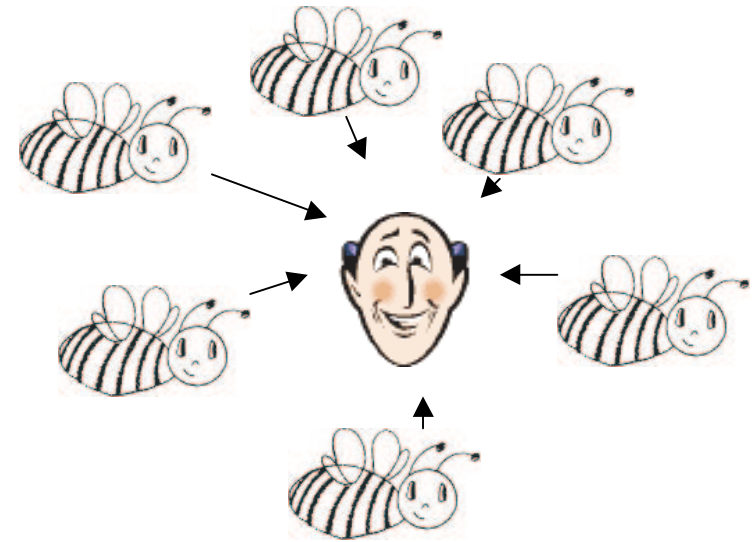
$$B_R = F_W(W) + F_X(X) + F_Y(Y) - F_Z(Z)$$

## W-panning : limiting cases



### Distant Object

- Narrow apparent width / solid-angle
- $W$  and  $|X, Y, Z|$  in ratio  $1 : \sqrt{2}$



### Ideal Surround Object

- Assume isotropic sound.
- $X, Y, Z$  all zero,  $W$  non-zero.
- $W$  and  $|X, Y, Z|$  in ratio  $1 : 0$

## W-panning : generalized formula

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To synthesize the ideal surround object modify single source equation with  $\gamma$ , and introduce overall gain  $\beta$ , from the sum of the spherical harmonic energies :

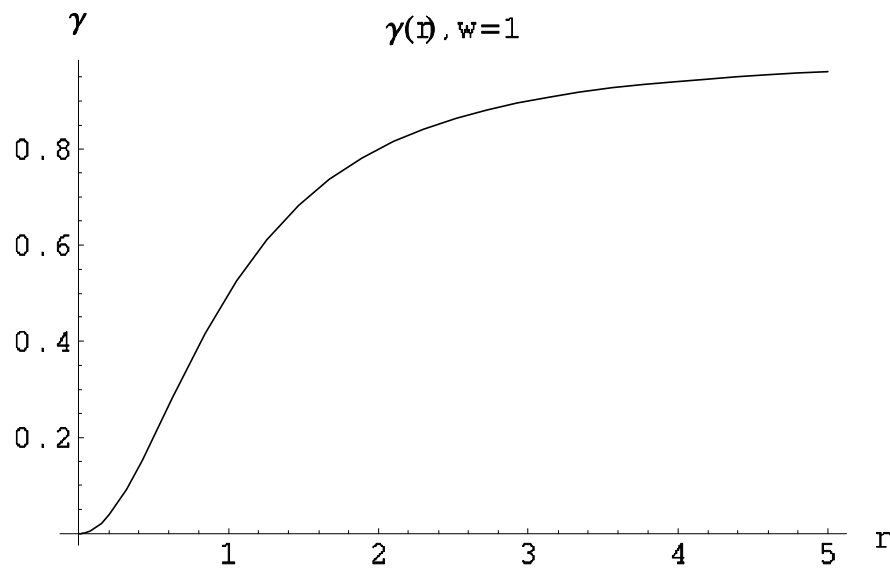
$$2\gamma W^2 = X^2 + Y^2 + Z^2 \quad 0 \leq \gamma \leq 1 \qquad 2W^2 + X^2 + Y^2 + Z^2 = \beta^2$$

Given  $\gamma$ ,  $\beta$  and source direction  $n$ , find that :

$$W = \beta(2 + 2\gamma)^{-1/2}, \qquad \text{where,} \qquad \alpha = \begin{cases} \beta(1 + \gamma^{-1})^{-1/2} & 0 < \gamma \leq 1 \\ 0 & \gamma = 0 \end{cases}$$

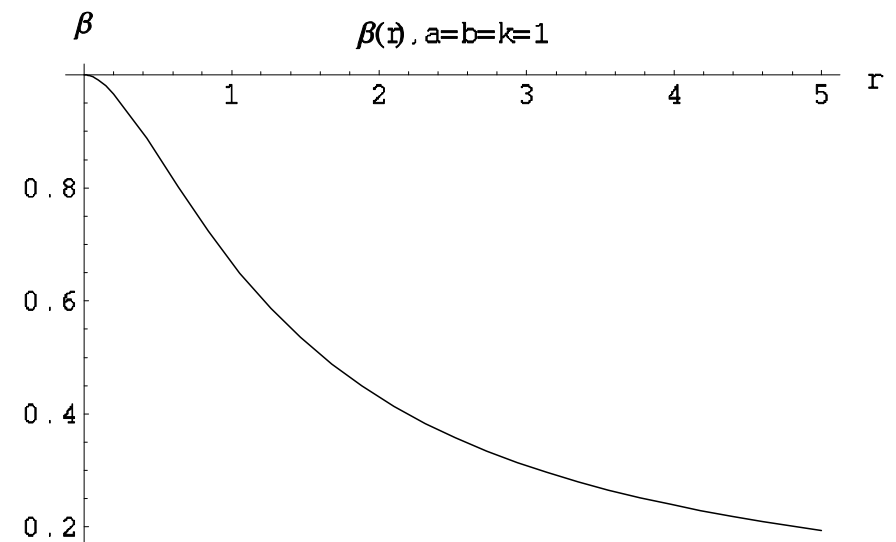
$$X = \alpha n_x, \quad Y = \alpha n_y, \quad Z = \alpha n_z$$

## W-panning : fitting $\gamma$ and $\beta$



### Conditions

- $\gamma = 0$  at  $r = 0$
- $\gamma = 1$  at  $r = \infty$
- Smooth at  $r = 0$



### Conditions

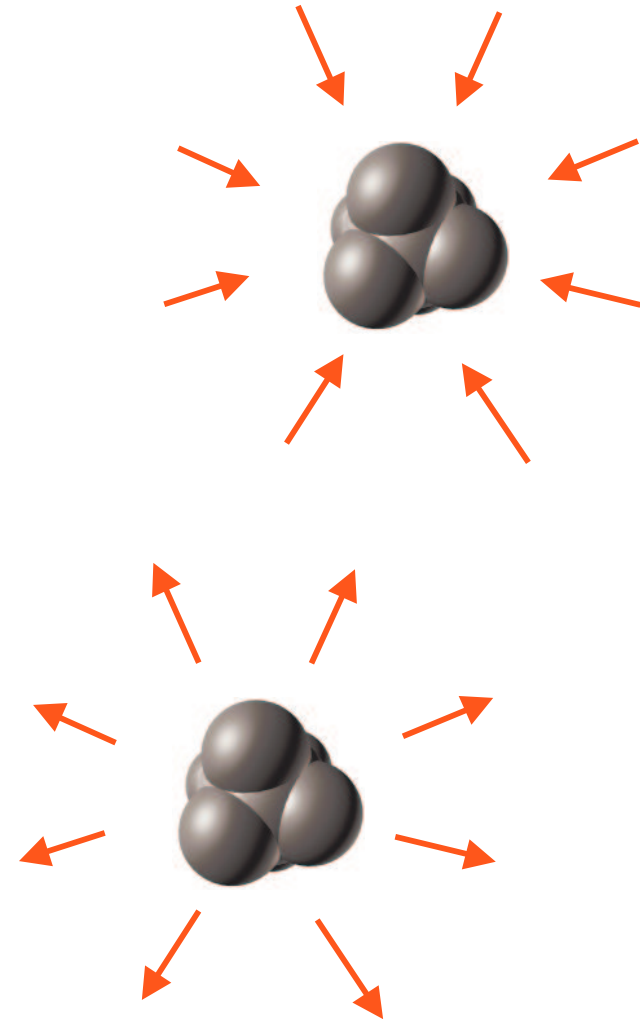
- $\beta = a$  at  $r = 0$
- $\beta \rightarrow br^{-k}$  as  $r \rightarrow \infty$
- Smooth at  $r = 0$

## O-format : spherical harmonic encoding of radiation

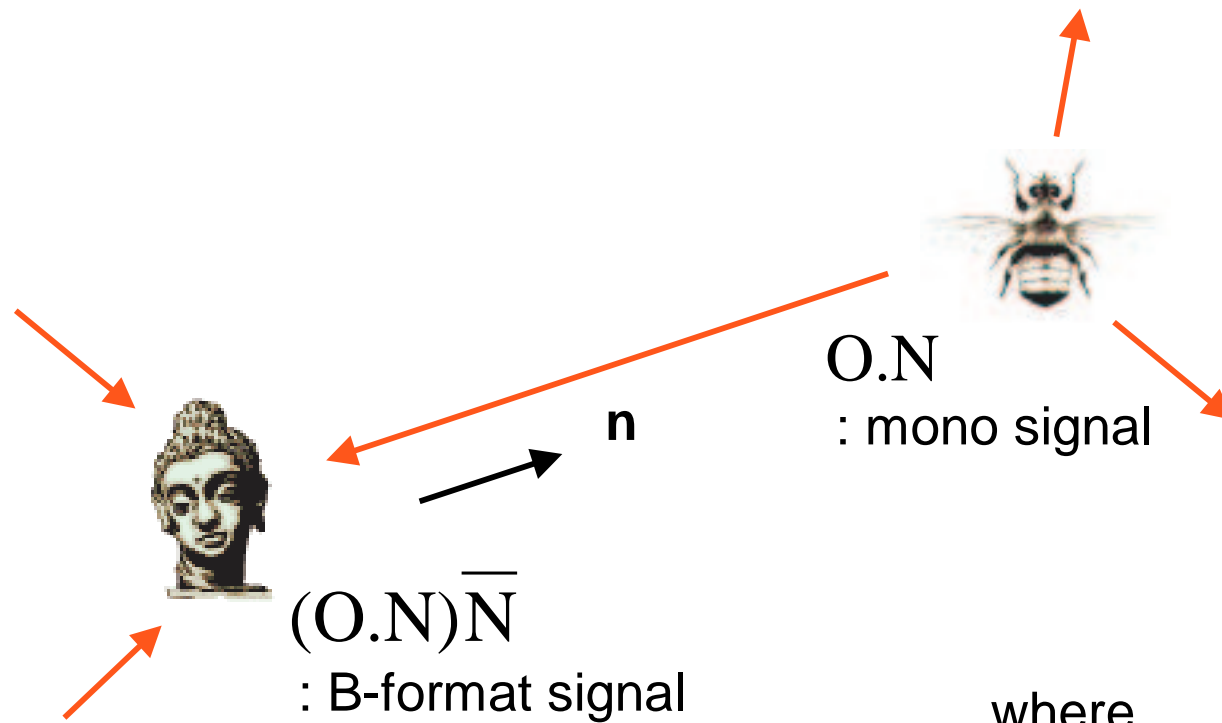
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B-format is the 1<sup>st</sup> order encoding of *incomming* sound waves, from a soundfield.

*O-format* is the 1<sup>st</sup> order encoding of *outgoing* sound waves, from a radiating source.



# O-format : rendering into B-format



where,

$$\bar{N} = \begin{pmatrix} \frac{1}{\sqrt{2}} \\ \mathbf{n} \end{pmatrix} \quad N = \begin{pmatrix} \sqrt{2} \\ -\mathbf{n} \end{pmatrix} \quad O = \begin{pmatrix} W \\ X \\ Y \\ Z \end{pmatrix}$$

- Simple into B-format.
- Could render direct into binaural.
- Can rotate O-format like B-format.
- Possible to create width with *dominance*.

## Conclusion

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- W-panning is simple, cheap and effective.
- It is smoother than existing techniques for penetrable objects.
- W-panning can sometimes be improved with frequency spreading.
- O-format is a cheap way to create a richer source radiation pattern.
- W-panning and O-format objects can be combined to create more complex structures.

