6.5 Using B-format Recordings for Object Synthesis

In the preceding spreaders a mono source was processed to spread the component frequencies over an arc, and thus create the impression of an object emitting sound with roughly uniform correlation across its surface or volume. Many real objects have radiation patterns with a much more detailed and interesting structure. These could be synthesized by exhaustive integration, or alternatively we could try and find some means for recording natural radiation patterns so that they can be reproduced.

To simplify the situation initially, consider the radiation pattern about a small, point like object. This cannot be measured directly with a single microphone, however a radiation pattern of comparable complexity can be generated by recording an environment with a soundfield microphone, then inverting the direction of signal travel. In other words a 1st order polar radiation pattern has been formed from a natural source. Let us call this *O-format*. O-format rotates like B-format to give the polar pattern of a rotated object. We are free to compose the environment to achieve a desired polar radiation pattern. Given a collection of point-radiators positioned in space about the listener, see **Figure 6.8**, the B-format signal is composed by encoding the signal received from each object into the direction to that object.

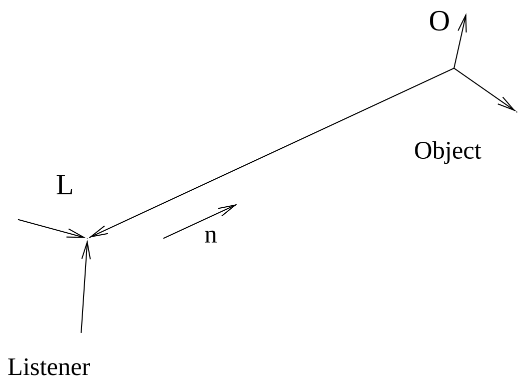

Figure 6.8: Encoding the signal from a point radiator into B-format.

Let the first-order radiation pattern of the object be written **O**, with components written the same as B-format for convenience.

$$\mathbf{O} = \begin{pmatrix} \mathbf{W} \\ \mathbf{X} \\ \mathbf{Y} \\ \mathbf{Z} \end{pmatrix} \tag{6.23}$$

Let the normal vector in the direction from listener to object be **n**.

Define

$$\mathbf{N} \quad = \quad \begin{pmatrix} \sqrt{2} \\ -\mathbf{n} \end{pmatrix} \tag{6.24}$$

$$\overline{\mathbf{N}} = \begin{pmatrix} \frac{1}{\sqrt{2}} \\ \mathbf{n} \end{pmatrix} \tag{6.25}$$

The 1st order spherical harmonics are cosine functions of direction, which are equal to the components of the normalized direction vector. The received signal, ignoring any distance gain adjustments, is the sum of the harmonics in direction $-\mathbf{n}$. This is just the dot product:

$$\mathbf{O}.\mathbf{N} \tag{6.26}$$

The encoding of the received signal in the received direction is

$$(\mathbf{O}.\mathbf{N})\overline{\mathbf{N}} \tag{6.27}$$

This is a linear transformation from O-format to B-format, and so must consist of rotation, reflection and dominance. Since the B-format signal has a component in only one direction, the transformation must be a maximum-dominance.

6.5.1 Spreading with Dominance

Continuously reducing the dominance factor below maximum level spreads the listener's field to give the impression of a non-point object, in the same way dominance was applied in Section 6.4.3. In terms of reflection, **R**, and dominance, **D**, with the degree of dominance given by λ this transformation is

$$\mathbf{R_n D_{-n,\lambda}} \tag{6.28}$$

6.5.2 Performance Usage

Performance by diffusion of an O-format signal offers new possibilities as the orientation of objects can be controlled in addition to their position.

The diffusion of an O-format source offers more control possibilities than for a mono source, as the source can be oriented by rotation and pseudo-object width generated using dominance. The reorientation of an object could have a dramatic effect on the content of the final sound, whereas the spread pan-pot designs of Section 6.3.1 cannot give control over the sound content in this way. For example, consider the O-format signal for an object emitting very different sounds in opposite directions. As the performer rotates this object the sound changes back and forth. This direct, yet natural, sound control cannot be produced with models that radiate equally in all directions. The ability to control the sound as well as the localization in a natural way offers many more musical possibilities.

Composite Radiators

Several point radiators can be grouped to move as one object. The summed image remains true B-format, but with directions encoded over an arc. Surface radiation can be modelled by biasing radiation away from the surface (**Figure 6.9**).

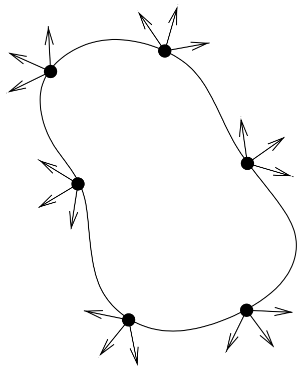

Figure 6.9: Extended surface radiator using composite point radiators.

This scheme provides an efficient method for modelling acoustic objects, without resorting to pseudo physical techniques like dominance. There is enough detail and structure to yield strong high-level cues about the movement and orientation of the object.

6.6 Soundfield Processing

Rotation and dominance have already been applied to the design of spreaders in 2 dimensions, but they are also useful in their own right for manipulating general soundfields. Details of calculation and implementation are presented here.

6.6.1 Rotation

There is 1 degree of rotation freedom in 2 dimensional space and 3 degrees in 3 dimensions. The space of orientations, is not immediately intuitive, but can be aided by parametrisation into Euler angles. These can conveniently be given in terms of the listener's head rotation which would achieve the same transformation on the soundfield: first an *azimuth* rotation about the vertical axis, then *elevation* in the vertical plane, and finally *twist* about the axis of vision.

To clarify the calculation of rotations the following is a precise definition in terms of the azimuth, elevation and twist. In matrix form, rotations about the X,Y and Z axis of angle θ acting on $\begin{pmatrix} \mathbf{W} \\ \mathbf{X} \\ \mathbf{Y} \\ \mathbf{Z} \end{pmatrix}$ are: