

7.2 Multichannel panning techniques

The panning of signals between more than two loudspeakers presents a number of psychoacoustic problems, particularly with regard to appropriate energy distribution of signals, accuracy of phantom source localisation, off centre listening and sound timbre. A number of different solutions have been proposed, in addition to the relatively crude pairwise approach used in much film sound, and some of these are outlined below. The issue of source distance simulation is also discussed.

It is possibly relevant here to quote Michael Gerzon's criteria for a good panning law for surround sound:

The aim of a good panpot law is to take monophonic sounds, and to give each one amplitude gains, one for each loudspeaker, dependent on the intended illusory directional localisation of that sound, such that the resulting reproduced sound provides a convincing and sharp phantom illusory image. Such a good panpot law should provide a smoothly continuous range of image directions for any direction between those of the two outermost loudspeakers, with no 'bunching' of images close to any one direction or 'holes' in which the illusory imaging is very poor.

7.2.1 Pairwise amplitude panning

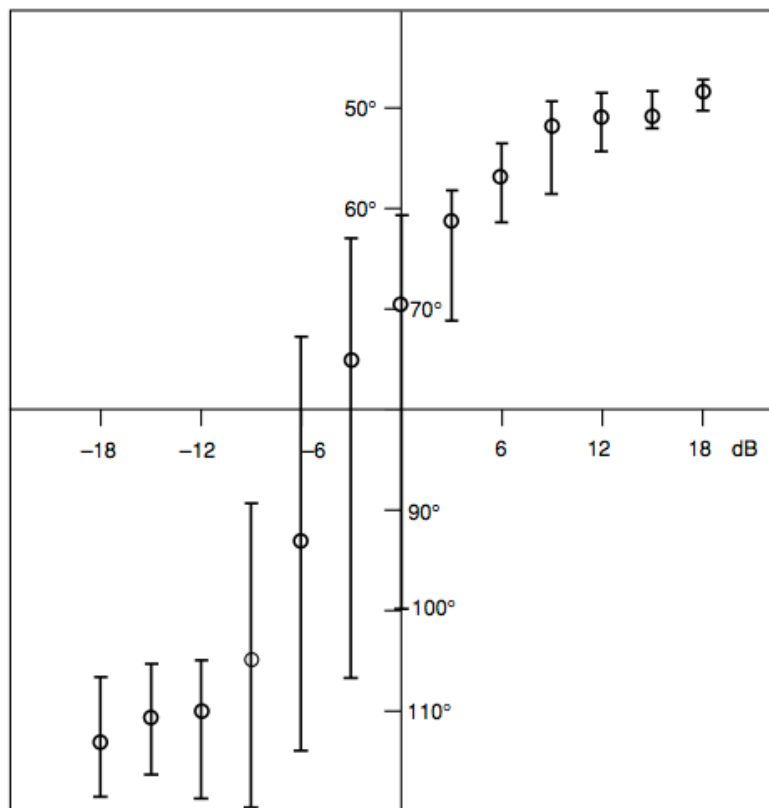
Pairwise amplitude panning is the type of pan control most recording engineers are familiar with, as it is the approach used on most two-channel mixers. It involves adjusting the relative amplitudes between a pair of adjacent loudspeakers so as to create a phantom image at some point between them. This has been extended to three front channels (LCR) and is also sometimes used for panning between side loudspeakers (e.g. L and LS) and rear loudspeakers. The typical sine/cosine panning law devised by Blumlein for two-channel stereo is often simply extended to more loudspeakers. Most such panners are constructed so as to ensure constant power as sources are panned to different combinations of loudspeakers, so that the approximate loudness of signals remains constant. Panning using amplitude or time differences between widely spaced side loudspeakers is not particularly successful at creating accurate phantom images. Side images tend not to move linearly as they are panned and tend to jump quickly from front to back. Spectral differences resulting from differing HRTFs of front and rear sound tend to result in sources appearing to be spectrally split or 'smeared' when panned to the sides.

In some mixers designed for five-channel surround work, particularly in the film domain, separate panners are provided for L-C-R, LS-RS, and front-surround. Combinations of positions of these amplitude panners enables sounds to be moved to various locations, but some more successfully than others. For example sounds panned so that some energy is emanating from all loudspeakers (say, panned centrally on all three pots) tend to sound diffuse for centre listeners, and in the nearest loudspeaker for those sitting off centre.

Joystick panners combine these amplitude relationships under the control of a single lever that enables a sound to be 'placed' dynamically anywhere in the surround sound field, but it is certainly true that the moving effects made possible by these joysticks are often unconvincing and need to be used with experience and care.

Those that proposed the 3/2 standard for surround sound were well aware of this problem and it was one of the main reasons why the surround channels were proposed as ambience, 'room' or effect channels to accompany three-channel stereo at the front. Recent data from Martin *et al.*, indicating how uncertain the location of side images was when panned in a 3/2 layout. Here we can see additional data from Theile and Plenge (1977) demonstrating much the same thing (see Figure 7.20).

Figure 7.20 Perceived location of phantom image versus interchannel level difference between side loudspeakers centred on 80° offset from front-centre, showing error bars. The forward loudspeaker is at 50° and the rear at 110°. It can be seen that the greatest uncertainty is in the middle of the range and that the image jumps rapidly from front to back. There is also more uncertainty towards the rear than the front. (After Theile and Plenge, 1977).



Research undertaken by Jim West at the University of Miami (West, 1999) showed that despite the limitations of constant power 'pairwise' panning, it proved to offer reasonably stable images for centre and off-centre listening positions, for moving and stationary sources, compared with some other more esoteric algorithms. Front-back confusion was noticed in some cases, for sources panned behind the listener. His work used a standard five-channel loudspeaker arrangement. Martin *et al.*, on the other hand, experimented with pair-wise and other panning laws using a uniformly distributed circle of eight loudspeakers (Martin *et al.*, 1999), but they also found that the pair-wise approach provided the most focused phantom images of all. These results suggest that this panning method may have some useful applicability to surround sound recording, and it has the advantage of being easy to implement. Users simply have to be aware of what is and is not reliable.

7.2.2 VBAP

The amplitude panning concept has been extended to a general model that can be used with combinations of loudspeakers in arbitrary locations, known as vector based amplitude panning or VBAP (Pulkki, 1997). This approach enables amplitude differences between two or three loudspeakers to be used for the panning of sources, although it is not clear how the inaccuracy of amplitude panning between speakers to the sides of listeners may be overcome.

7.2.3 ‘Ambisonic’ and other advanced panning laws

A number of variations of panning laws loosely based on Ambisonic principles have been attempted. These are primarily based on the need to optimise psychoacoustic localisation parameters according to low- and high-frequency models of human hearing. Gerzon based his proposals on the Makita theory of low-frequency localisation (Makita, 1962) (that is essentially Blumlein-style summing localisation based on interaural phase difference resulting from inter-speaker amplitude difference, represented by sine and cosine gain components forming a so-called ‘velocity direction’), and on high-frequency energy- vector-based localisation based on the power differences between the channels. He rightly points out that the localisation position implied by these two vectors (velocity and energy) should be similar or the same for as many angles as possible, and that it rarely is with conventional amplitude panning except at the extremes of the image and in the centre. He therefore proposes a variety of psychoacoustically optimal panning laws for multiple speakers that can theoretically be extended to any number of speakers (Gerzon, 1992e). Gerzon’s own examples only extended up to four equally spaced loudspeakers. Some important features of these panning laws are:

- There is often output from multiple speakers in the array, rather than just two.
- They tend to exhibit negative gain components (out-of-phase signals) in some channels for some panning positions.
- The channel separation is quite poor.