feature | surround sound explained

you are surrounded

SURROUND SOUND EXPLAINED * PART 1

Surround sound in one form or another has been a part of the film industry for many years, but the emergence of affordable digital technology has now pushed it into the domestic mainstream. **Hugh Robjohns** begins *SOS*'s definitive guide to surround and its implications for the hi-tech musician.

I think it would be a pretty safe bet to assume that everyone reading this will have some idea of what surround sound is all about. After all, it has been with us in various guises since the production of Walt Disney's *Fantasia* in the 1940s, and the hype 'surrounding' its recent incarnations (excuse the pun) is very hard to overlook, both in professional and consumer circles. Nevertheless, just to make sure we are all talking about the same thing, by surround sound I refer to a means of audio reproduction that involves more than two speakers -- that is, something beyond conventional stereo, requiring four, five, six or more loudspeakers positioned around the listener at specific locations.

You might already have had some contact with surround sytems in a domestic environment, in the form of a four-channel Dolby Pro Logic-equipped video system, or even a five- or six-channel DVD video 'home theatre' setup. However, with the recent publication of the final specifications for DVD audio-only discs (DVD-A) and consequent release of suitable players and media onto the marketplace, not to mention the growing libraries of competing (but incompatible) surround-sound formats such as Digital Theatre Systems' DTS and Sony's Super Audio CD (SACD) and their associated players, it seems a good time to give the whole topic a thorough examination in the pages of *Sound On Sound*.

Over the coming months, we will take a look at what surround sound is all about, where it came from, where it is going and, most importantly of all, why it is relevant to you! We will work through some of the theoretical aspects of producing and presenting sound in surround, and look at how the professionals are handling the format, both in studios and in mastering environments. Perhaps of more direct relevance, we will also examine ways that you can set up surround-sound monitoring and perform mixes in surround -- either using your existing equipment or, if your equipment does not support surround already, we will provide some suggestions as to how to acquire the ability for the smallest outlay of cash.

Surround For The Consumer

Although many people subscribe to the view that surround sound will never be as popular or as practical a medium as stereo -- primarily because of the unacceptable domestic demands imposed by six (or more) loudspeakers -- the technology is certainly available to support it in both professional and domestic environments. What's more, our understanding of the psychoacoustics involved is far more advanced than it was when the ultimately unsuccessful domestic quadrophonic systems (of which more later in this article) were launched 30 years ago.

It must be said, however, that the greatest enthusiasm for surround today comes from equipment manufacturers, who are extremely keen to promote it. From their point of view, their markets have become fully saturated; stereo CD systems can be found in virtually every home in the developed world, and so profits are either levelling off or falling. The only way to boost their sales is to persuade the punters to part with their money for new hardware and software all over again -- and that means the introduction of a new format.

There is nothing new in this approach -- we saw the same thing at work with the launch of CD in the first place, and with Minidisc and MP3 more recently. In the context of surround sound, we are now seeing it all once again with DVD Video, SACD, DTS, and now DVD Audio -- all of which share the generic DVD platform.

However, the main problem from the consumer's point of view is that these are mutually incompatible formats -- a problem that is often the Achilles heel of Japanese manufacturers, who seem always to want to push their own bespoke designs, rather than agree from the outset on a range of wholly compatible formats. While a lot of consumers have already bought standard DVD-V players -- although not as many as the manufacturers would have liked -- a significant reason for the slow uptake has been the confusion of formats and the almost continual upgrading of the DVD format specifications.

Consumer DVD magazine reviews are frequently highlighting DVD feature film releases with extended functionality which is not accessible on certain machines at all, or machines which can not play video discs without the assistance of an external audio format converter to handle (for example) DTS-encoded tracks.

At the present time, very few DVD players indeed can handle SACD discs or the full set of DVD-A requirements -- although many manufacturers have been promising true 'universal' players capable of extracting any information from a DVD-style disc for some time. Until universal players are the norm, though, the public at large cannot be confident that any disc they happen to buy will play back properly. Unsurprisingly, these kinds of issues tend to make the consumer wait until standards are established. We have just reached the point where this is starting to happen -- the DVD-A specs are now cast in stone, SACD is becoming widely recognised and endorsed by the record companies, and the manufacturers have sorted out most of the licensing deals. Multi-format or 'Universal' machines are just beginning to come on to the market and will hopefully become the norm in a short space of time (say within three years or so).

Surround for the Musician

From the musician's point of view, surround provides a far more challenging and potentially more creative environment in which to work, although there are also some significant fiscal and technical implications in terms of equipment and facilities (more on these in a couple of months). The bottom line, though, is that the record companies and other commissioners of music (film, television, computer games, and so on) are increasingly expecting or demanding surround mixes because of their intrinsic commitment to surround formats in

general. The general public, too, may well start to expect everything to be presented in surround -- if only so that the pretty little light on the hi-fi comes on and those extra speakers that came with the new stereo produce some sound in the dining room (...and you think I'm joking?)!

To me and my colleagues at *SOS*, it therefore seems very sensible that if you have any interest in working in surround at all, you should start thinking about the whys and wherefores now, and begin formulating a plan to acquire both the gear and experience necessary to work comfortably in the medium. Hopefully, this new series will go some way to helping you achieve those goals.

Lessons Of The Past

Before diving headlong into the technicalities of the subject, we should reflect a little on the relevant surround experiences of the past. A sizeable proportion of the *SOS* readership will be old enough to remember Quadraphonic systems (even if only as a distant recollection of Uncle Bill's weird hi-fi) and might have wondered why the format disappeared so quickly. It might be instructive to consider the reasons for these past, failed systems to avoid making the same mistakes again.

In the beginning of recorded sound, over a century ago, one-channel (mono) recording was all that was possible. However, within a surprisingly short space of time, the science of sound recording had evolved tremendously, and amongst the possibilities brought about by the electronic age was multi-channel sound, which attracted the attention of many inventors. The introduction of the thermionic valve (or vacuum tube in America) by Lee de Forest in 1907 enabled electrical amplification and bought about the means of combining and controlling signals from multiple microphones, not to mention the ability to record and replay such signals from multi-channel media (initially with optical tracks on film).

By the 1930s a lot of effort was being put into finding better ways of reproducing 'soundscapes'. The word 'stereo' (a contraction of 'stereophony', from Greek roots meaning 'solid sound') was originally used to refer to reproduction systems employing multiple sound channels. The early experiments in 'stereo sound' were attempted to recreate life-like three-dimensional sound images using a variety of techniques, all of which employed at least two channels and often many more.

Building on the pioneering work during the first few years of the 1930s of such industry luminaries as Alan Blumlein of EMI and Harvey Fletcher of Bell Labs, the typical 'stereo' (ie. two-channel) systems we have today gradually evolved (see Figure 1(a) elsewhere in this article). In fact, Blumlein's work on coincident stereo has remained the foundation and fabric of all domestic stereo replay systems, as well as many common studio and location recording techniques, which have remained completely unchanged in 70 years! The work of Bell Labs can also be traced directly to the top of the family tree of replay formats employed universally in the cinema industry -- particularly in the use of a third, front-centre channel to localise dialogue and key actions to the centre of the vast projection screens used during the first heyday of the worldwide film industry.

The first public use of genuine, discrete-track surround sound -- in the context that we would understand today -- was by Walt Disney in his famously surreal animation film, *Fantasia*, which married animated mini-features to excerpts of popular orchestral music. The conductor for the original production, Leopold Stokowski, had previously been working closely with Bell Labs in their development of various advanced music recording systems and techniques, and it was inevitable that he would act as a conduit for their

expertise in the Disney project. These combined talents
and resources proved inspirational, and led directly to the realisation of what can only be
described as a technological masterpiece, over 60 years ago!

For the first time in cinematic history, a film's sound stage was designed to completely
surround the audience -- up to eight separate music and effects tracks were mixed and
panned, live, during each performance (see above). Obviously, cinemas were not equipped
to handle such complex or pioneering technical requirements, so Disney toured the film
across the United States, complete with its own technical crew and reproduction system
(christened Fantasound), to great acclaim. Unfortunately, the 'roadshow' was brought to a
premature end by America's entry into World War II, and this innovative surround-sound
technology was never used again in the same form.

Disney and Bell Labs were undoubtedly the first pioneers of surround sound, and had to
develop many original techniques and technologies for the project. For example, to be able
to pan sounds around the auditorium they actually had to *invent* pan pots, as nothing like
them had existed before. They also had to invent multitrack audio recorders so that
different orchestral sections could be replayed, and therefore positioned, independently. To
obtain sufficient separation to allow the various orchestral sections to be manipulated
independently, they also developed close-microphone techniques, overdubbing, and even
click-tracks -- all techniques we take for granted today, but revolutionary at the time.

The advent of magnetic film soundtracks in the 1950s maintained a limited degree of
surround technology in the cinema. The popular 35mm Cinemascope films employed four
tracks, for example, and there were six on the prestigious 70mm Todd-AO format. Both of
these mainly used the additional tracks to allow side and rear sound effects, in addition to
the widely adopted three frontal channels.

The Quad Squad

The first time surround sound raised its head in the consumer environment was with
quadraphonic (or quad) systems in the 1970s. Once again, the introduction of these new
formats was principally driven by hardware manufacturers, who were trying to expand the
market after it reached near-saturation with stereo record and tape players. Unfortunately,
the whole quad era was a commercial disaster, principally brought about by far too many
incompatible formats and a very confused public, but also because the fundamental
concept didn't actually work very well!

At this time, surround sound meant four channels -- essentially a conventional stereo pair at
the front and another at the rear, with the angle between adjacent speakers being 90
degrees. Conventional stereo requires the loudspeakers to subtend an angle of 30 degrees
either side of the centre line of the listening position to produce the most coherent and
stable stereo imaging. If you move closer to the speakers, such that their relative angle
increases to 90 degrees (±45), you will find that the imaging quickly collapses into puddles
of sound at the speakers with the slightest movement either side of the central axis. Even if
you manage to remain in the incredibly narrow 'sweet spot', the imaging is highly unstable
and distorted unrealistically. This is precisely the problem encountered with quad systems -
- only made all the worse by suffering not only unstable frontal imaging, but also virtually
non-existent side and rear imaging. Essentially, sound tended to puddle unconvincingly
around the speakers, or leap about disconcertingly when panned around.

At the time, little had been done in the way of scientific research into the psychoacoustic
effectiveness of such a system, and not much was known about how human hearing
deduces directional information. The bottom line was that most Quadraphonic systems

failed to reproduce anything remotely convincing by way of a surround soundstage. In particular, achieving stable and solid images across the sides proved to be a major hurdle, and the systems only worked at all if the listener remained in a very small, highly impractical 'sweet-spot'.

Matrixing

Although there were a couple of bespoke, discrete four-channel tape-based systems (quad reel-to-reel and eight-track cartridge formats), most quadraphonic systems involved some form of signal matrixing. In this context, the idea of a matrix is to combine the original four sound channels -- corresponding to the signals required in each of the four loudspeakers -- into (typically) two channels for recording or transmission. This is normally done in such a way that the resulting two-channel signal remains broadly compatible with conventional stereo and mono replay -- in other words, it is 'backwards compatible'. This was the idea with domestic quad systems -- that by employing stereo matrixing, they could offer playback of quad, stereo and mono records from the same record player.
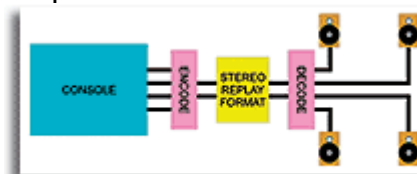

On replay a special decoder is employed to reconstruct the original four channels from the matrixed two-channel signal for auditioning through the loudspeakers. This arrangement is often referred to as 4:2:4, because the four original channels are matrixed into two channels for transmission and storage, but reconstituted into four channels for replay. Lexicon and RSP Circle Surround both manufacture 5:2:5 systems today, but the Dolby surround (Pro Logic) format, of which more towards the end of this article, remains a 4:2:4 system.

The problem with matrix encoding is that you can never reconstruct the original four channels perfectly: something is always lost through the process -- normally separation or isolation between the four channels! Or, put another way, matrixing introduces a lot of crosstalk. Whilst there are some very clever methods to minimise this and improve the situation, all matrixing produces significant and undesirable side-effects. This is why all of the current surround-sound formats maintain multiple (more than two) discrete channels all the way from origination through to the loudspeakers in the listening environment, as shown in Figure 1(b) elsewhere in this article.

The side-effects of matrixing are not so apparent in the feature-film environment, but in a quadraphonic surround system, the crosstalk severely limits the system's ability to image accurately. As a result of this, few, if any, quad systems really came close to delivering the performance that their marketing propaganda promised in the '70s.

Another problem hampering the domestic takeoff of quad was that there were a great many competing (but largely incompatible) quadraphonic surround systems in existence during the mid-to-late '70s. UMX (also known as UD4) from Denon and Columbia, and CD4 Quadradisc (JVC & RCA), avoided the inherent problems of matrixing by employing a separate high-frequency subcarrier to convey the rear-channel information (in a similar way to that used by stereo FM radio). UMX and CD4 were only available on vinyl records and needed specialised phono cartridges and decoders for surround-sound replay. Although fully backwards-compatible with stereo record players, the inevitable wear and tear of the disc groove quickly destroyed the high-frequency information carrying the rear-channel signals.
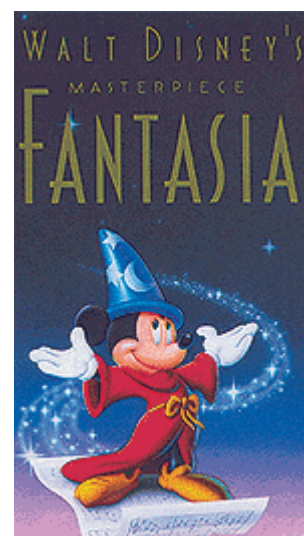
Matrixed systems of the period included SQ (CBS & EMI), QS (Sansui & Decca), 45J (National Research Development Council, or NRDC), Stereo 4 (Electrovoice), Dynaquad (Dynaco), and Matrix H (BBC). None of these formats survived beyond the start of the 1980s, although a couple did form the basis of further developments which are still with us today. For example, the 45J and Matrix H systems formed the roots with what is now known as Ambisonics UHJ -- a more recent simplification of the original Ambisonics surround system, which is truly periphonic -- that is, capable of conveying height information as well as horizontal surround sound.

Ambisonics deserves a separate investigation as it is a kind of purist surround technique -- the surround equivalent of coincident mic techniques, you could say -- which was way ahead of its time when it was invented over 25 years ago. We will return to it again later in this series, because it is still very much alive and offers a great deal of format-independence in gathering and processing surround sound.

Suffice to say, for now, that UHJ-encoded CDs are widely available and have been for many years, and are capable of producing very accurate surround images when decoded correctly. Unfortunately, Ambisonic decoders have been few and far between, but growing interest in the format, combined with the almost universal use of digital signal processing in surround-sound controllers, means that implementing the complex Ambisonic decoding algorithms is now fairly straightforward and more domestic decoders are beginning to offer the feature.

Dolby Surround

Another surround format which has survived the quadraphonic era is the 'MP Stereo' format produced by Dolby Laboratories, which first came to popular recognition with the original Star Wars film in 1976. Dolby had been involved with the film industry for some time as its Dolby A noise–reduction system was widely employed in an attempt to improve the relatively poor noise performance of optical soundtracks on 35mm film release prints.

By building on the work of the quadraphonic matrix encoders and decoders (and incorporating some of their own ideas), Dolby were able to provide a reliable four-channel system which was fully compatible with standard mono and stereo replay systems, but which could also envelope the audience with atmospheric effects to enhance significantly their involvement in a film.

The original Dolby system was not intended to recreate a stable 360 degree soundfield from four corner speakers as the quadraphonic systems had been, but was designed to encode signals for the prevailing three front speakers, which provided good frontal imaging, plus a fourth feed for numerous surround speakers along the sides and rear of the

Fantasia In Surround On DVD

The original *Fantasia* film is now available on DVD in a specially restored, uncut edition which has been remastered to celebrate its 60th anniversary, with its soundtrack remixed into surround according to the original production notes.

The restored material includes both the intermission and narration, neither of which have been incorporated in the film since its original theatrical release in 1938. In addition to the memorable scenes of Mickey Mouse as the Sorcerer's Apprentice, and plump hippos performing ballet in tutus, this latest release also contains various behind-the-scenes material including audio interviews with the late Walt Disney and some insightful commentaries by those who contributed to the reproduction of the original film. It's highly recommended and a justifiable purchase as *the* original, definitive surround reference!

Fantasia 2000, also available on DVD, carries on where its predecessor left off, with seven completely new segments in addition to the ever-popular Sorcerer's Apprentice. The musical excerpts span Beethoven to Gershwin to accompany everything from flamingos with bobbing yo-yos, to a 'city in bluesy motion'! Although not as revolutionary as the original, this latest film still makes interesting use of the surround medium.

[W] www.disney.com

auditorium, which were all fed from a single 'Surround' channel. The four-channel stem (Left, Centre, Right and Surround, or LCRS) fed into the matrix encoder at the recording stage had total separation between channels, but once encoded into the two-channel matrixed signals (known as Left-total and Right-total, or LtRt), that separation was all but lost completely (see Figure 2 above).

Separating the four components on replay was a major headache, as with many of the matrixed quad systems, but the process was enhanced by a couple of psychoacoustic tricks, including the use of (originally) analogue delay and bandwidth limiting (100Hz-7kHz) on the rear surround channel. The delay ensured that crosstalk from the front channels into the rear arrived at the listener long after the front-channel sounds, and was therefore not perceived, let alone objectionable.

The analogue (bucket-brigade) delay lines of the time were very noisy, but the use of a simplified form of Dolby's B-type noise-reduction helped a lot. A very clever active steering system was also developed to increase the perceived separation, cancelling some of the crosstalk in adjacent channels in the presence of a 'dominant' sound signal. Although the steering system improved the separation between channels, it had some 'entertaining' side effects and, as a consequence, Dolby made it mandatory to monitor the results of the complete encode-to-decode process when mixing a soundtrack in their format. In that way, the inevitable side effects of the matrix decoding could be minimised or mitigated at the mixing stage.

The original cinema system used the 'Motion Picture' or MP matrix, and was trademarked as 'Dolby Stereo' in cinema applications. When films were released on video with Dolby MP-encoded soundtracks, the first domestic incarnations of the decoder (around 1982) were trademarked 'Dolby Surround', although these systems used a passive decoding arrangement which provided appalling channel separation. Around 1988, the original professional MP matrix decoder was redesigned and manufactured as an integrated circuit, making it cost-effective for use in the consumer mass market, where it was marketed as 'Dolby Pro Logic'. The system has now been in widespread use across the world for over a decade, and is frequently integrated into domestic hi-fis, televisions, and computer consoles. Last year, Dolby launched 'Pro Logic II' -- an updated version of the complete encode/decode process which, whilst still compatible with existing MP-matrix encoded media, provides enhanced results with non-encoded music and other stereo sources for replay over a 5.1-channel surround monitoring system.

Since Dolby Stereo (aka Dolby Surround or Dolby Pro Logic) is still a standard release format, and is employed on countless computer games, as well as in a significant proportion of radio and television broadcasting, we will come back to looking at it next month.

Next Month

In the next part of this series, we'll take a closer look at the two current surround-sound technologies which have survived from the past: Ambisonics and Dolby Stereo. They both have applications in modern surround-sound productions, and both involve techniques and technologies which provide a foundation for discrete 5.1 systems and beyond. 📧

Glossary
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SOUND ON SOUND

Europe's No1 Hi-Tech Music Recording Magazine Sound On Sound

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