Microphone systems used for Surround Sound pickup

— and their use at Wimbledon tennis and The Proms

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This article briefly describes some of the microphones developed specifically for Surround Sound pickup, along with several of the main Surround acquisition systems on which the majority of the dedicated Surround mics are based. It offers some personal advice on whether a particular system is suitable for use in this recording environment or that. Some microphone systems are obviously more intrusive "in shot" than others, depending on the location.

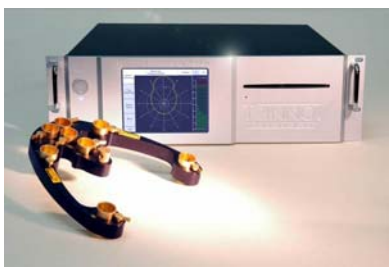
The author also describes two major outside broadcasts that have involved Surround Sound mixes – the Wimbledon Tennis Championships and the BBC Proms Concerts from the Royal Albert Hall in London.

The types of microphones and the style of their use for Surround acquisition are as varied as there are sound mixers! Much thought has been given to this subject over many years by many different people, some with an engineering base, some of them practitioners, and others who are theoreticians. Most methodologies are developments of stereo recording techniques with added components to derive the Surround information.

I'll start with three systems designed specifically for Surround. One requires the use of a computer to generate and adjust the output to obtain the required Surround soundfield. Another requires a matrixing box to generate the Surround. The third produces separate discrete outputs but, because it is built as a complete system, I won't include it in this section; instead, it will be discussed later in the section on "discrete" systems.

Surround microphones

Trinnov SRP



This "High Spatial Resolution" microphone array consists of eight near-coincident omni-directional (omni) capsules in a horseshoe-shaped mount. The outputs of these microphones are passed through a computer-controlled matrixing system, which converts timing differences produced by the array into amplitude differences. It also allows spatial (directional) control of the microphone to control the reverberant field. The manufacturer claims, among other things, optimized channel separation, an enhanced "sweet spot", production of good phantom images over the full 360° soundfield and good quality downmixing to stereo and mono.

This is a complex and expensive microphone, difficult to use in the outside broadcast external TV environment (as opposed to inside buildings) due to the necessarily large windproofing arrangements required.

For further information – **http://www.trinnov-audio.com/products.php**.

SoundField

The SoundField microphone is based on the concept that any Surround audio event can be represented by four basic bits of information:

- the front-to-back or depth information (X);
- the left/right information (Y);
- the up/down information (Z);
- the central point (W) to which the other three elements are referenced.

Collectively, these four elements are referred to as B-format and are combined via a matrix to produce any Surround audio format from 4.0 all the way to 22.2, with height information if required. It just depends on the design of the matrix.

The microphone head consists of 4 x figure-of-eight capsules and 1 x omni capsule, electronically combined to form an absolute coincident array. Because the array is always referenced to the same central point, any time- or phase-related anomalies don't exist, giving extremely good fold-down to stereo and mono signals.

It is easy to use and quick to set up, is remotely controlled from the accompanying matrixing box and is comparatively cheap.

For further information – **http://www.soundfield.com/soundfield/soundfield.php**.

Holophone H2-PRO

The Holophone H2-PRO claims to emulate the characteristics of a human head. Sound waves "bend around" the head and are picked up by eight omni microphone "elements" to provide spatial audio imaging. The individual elements combine with the spherical body to act as an "acoustic lens". The information relating to the complete soundfield can be replicated without the use of additional microphones.

The Holophone H2-PRO is capable of recording up to 7.1 channels of discrete Surround Sound (Left, Right, Centre, LFE, Left Surround, Right Surround, Top (Height) and Centre Rear). These co-relate to the standard 5.1 channels and add a top channel for formats such as IMAX and a centre rear channel for extended Surround formats such as Dolby EX and DTS ES. You can have total flexibility over the discrete Surround audio signals and choose to use whichever channels any particular Surround project requires, as the channels remain discrete all the way through the process.

It is simple and relatively cheap to use as there is no processing involved, providing just the eight discrete outputs from the "elements". However, the device relies on the quality of those microphone "elements" for the acceptability of its audio performance.

For further information – **http://www.Holophone.com/products.html**.

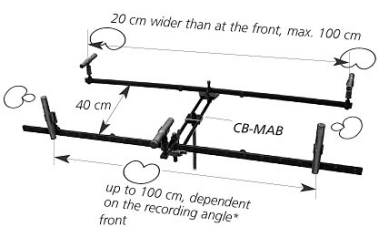
Discrete microphone systems

This is the most contentious and widely discussed area of Surround recording. Most microphone setups in this category are variations on three basic formats ... and those formats themselves being

based on the Decca Tree stereo array. They are based on combinations of spaced or near-coincident omni and directional microphones.

OCT Surround – supercardioids / cardioid / omnis

This is probably the simplest of the setups that can be used for spaced or near-coincident Surround acquisition and the basis for many different techniques. It's a derivative of the "Decca Tree" system with the long forward arm replaced by a very short one and the omni mics used in the Decca Tree replaced with microphones of different polarities.



The basic OCT Surround array consists of three microphones arranged in a line on a bar, the two on the extremes being supercardioid microphones pointing +/- 90° to the side. The central, forward-facing microphone is a cardioid, usually mounted about 8 cms forward of the bar. Variations on this setup include mounting omni microphones (low-pass filtered) at the hypercardioid microphone positions, or at the central cardioid mic position, to extend the lower frequency response of the whole setup. This OCT "front" system is combined with one of the many "rear pickup" systems, such as the Hamasaki Square or the IRT Cross, or even a simple pair of spaced cardioids pointing backwards, to pick up the required rear image.

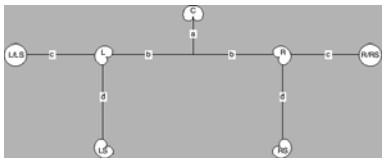
For further information –
http://www.hauptmikrofon.de/theile/Multich_Recording_30.Oct.2001_. PDF

"Williams" Array – cardioids

This method has also generated a swathe of variations but is based on a single principle. That principle was put forward by audio consultant Michael Williams and says that, when putting an array together, a "critical link" is made between the angles of coverage of adjacent pairs of microphones in that array, so that their coverage angles don't overlap but just touch – in effect, a modified one microphone-per-speaker format. In theory this gives a very even representation of the soundfield.

The array consists of five cardioid microphones, the L/R mics are one metre apart and the centre mic is mounted 25cms in front of the bar. The rear facing cardioids are about 60cms apart and some 250cms behind the bar. The front L/R capsules are +/- 70° and the rear mics are +/- 150° with reference to the centre.

Fukada Tree – cardioids and omnis



Akira Fukada, a senior recording engineer from NHK in Japan, proposed this array. It is also based on the Decca Tree approach in that it retains the long front arm but changes the omni capsules in the original to cardioids angled between +/- 130° and +/- 150° relative to the centre. Each microphone is evenly spaced from the centre point at about 1 to 1.5 metres. Two omni outrigger mics are added to the array, in line with the L/R mics and a similar distance from their corresponding cardioid partners.

Two cardioid microphones are added to cover the rear, in line with the forward-facing L/R microphones, coincidentally if required but no more than 2 metres behind them, and at an angle of between +/- 60° and +/- 90°.

Abbreviations

L/R	Left/Right	**M+S**	Mono and Stereo
LFE	Low-Frequency Extension	**PA**	Public Addressing
LS	Left Surround	**RS**	Right Surround

When mixing the five main front and rear elements, there appears to be a separation of the front and back soundfields. The omni outriggers are used to blend the two together by being panned front to back and mixed into the soundfield appropriately.

For further information – **http://www.tonmeister.ca/main/textbook/node840.html**

Hamasaki Square – figure-of-eights

Kimio Hamasaki of NHK introduced this technique. All of the above discrete techniques have included frontal pickup in their design. The Hamasaki Square was invented as a means of picking up the diffuse soundfield in a reverberant environment. It complements any of the standard stereo recording techniques such as OCT or Decca Tree for reproducing Surround ambience.

It consists of four figure-of-eight microphones fixed in a square (dimensions usually between 2 and 4 metres), with the axis of each of the four microphones at right angles to the direct sound. Because microphones are aimed sideways, they effectively prevent unwanted direct sound from appearing in the Surround channels. In a situation with an audience below the array, the off-axis presentation of the microphones also helps to control excessive audience pickup.

The four microphone signals are routed discretely to the Left, Right, Left Surround and Right Surround channels.

For further information – **http://www.tonmeister.ca/main/textbook/node843.html**.

Schoeps "Head" – omni + figure-of-eight

This technique was devised by an American audio engineer, Jerry Bruck. The microphone consists of the Schoeps KFM 360 sphere microphone with two forward-facing figure-of-eight capsules placed near-coincidentally to the omni capsules in the sphere. The outputs of these capsules are fed into a matrix box, from which are derived four virtual forward and rear facing mics. A four-channel Surround output, together with a matrixed Centre channel and an LFE channel, are thus produced from the matrix box.

The polar patterns of the virtual microphones can also be changed to give a variety of pickup characteristics if required.

If the four unprocessed mics are recorded directly, the Surround effect can be manipulated at a later date by being played back through the matrix box. This makes the system very similar to the Sound-Field B-Format system.

For further information – **http://www.schoeps.de/PDFs/SCHOEPS_surround-brochure.pdf**.

MSM - cardioids / hypercardioids + figure-of-eight

This is a near-coincident technique, deriving a Surround effect with three capsules (usually two cardioids and a figure-of-eight), the outputs of which may be simply matrixed in a sound-mixing desk to provide a four-channel soundfield.

Of all the techniques, this must be the simplest and cheapest to set up and use. In my view, it is certainly the easiest system to use and is very portable – usually being small and light – and thus is eminently suitable for boom and/or rod work. It requires only three channels of recording media to obtain 4.0 Surround Sound!

Summary

Nearly all of the systems discussed have varying out-of-phase components and therefore different phase performance when folded down to stereo and mono. Compatibility with stereo and mono is

something that broadcasters are very much aware of, as most of their audience still listen that way, be it via radio or television transmissions. The Surround audio can sound as wonderful as you could possibly wish in the recording control room but, if the listener at home receives a poor quality stereo

The BLITS 5.1 tone generator

The BLITS 5.1 tone generator was designed in conjunction with BSkyB to provide line identification of Surround Sound signal sources. Provision is made for identifying stereo, channel phase and the six 5.1 audio channels: L, R, C, LFE, LS and RS.

The tone generator may be switched between the 5.1 and the stereo oscillator sequences, and individual 5.1 sequences may be "looped". The unit also includes a discreet EBU tone source.

With "Tone output Select" selected to 5.1 and "5.1 cycle" selected to Normal, the BLITS tone generator will output the following tone sequences:

- Left/Right identification: 1 kHz 0 dBu tone on both Left and Right channels, with four interruptions on the Left channel. The four interruptions will differentiate the ident from the standard EBU or GLITS tones.
- Phase check: 2 kHz tone at –6 dBu on all audio channels.
- Channel identification: The sequence is:

  (Front) Left – 880 Hz

  (Front) Right – 880 Hz

  Centre – 1318.51 Hz

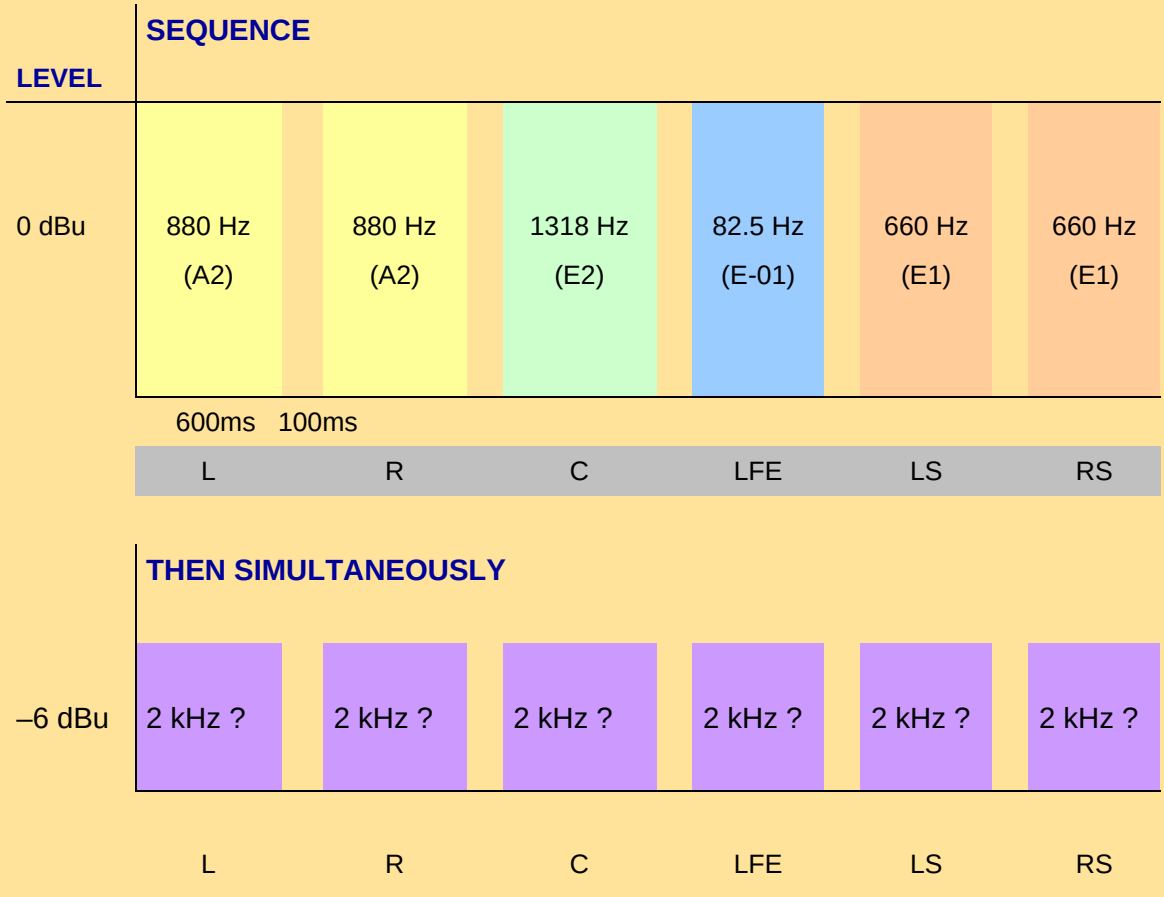
  LFE – 82.407 Hz

  Left Surround – 659.255 Hz

  Right Surround – 659.255 Hz.

These frequencies correspond to notes A4, A4, E4, E0, E3 and E3 respectively.

The Blits generator may be locked into any one of these cycles using the 5.1 cycle push button.



transmission because your Surround mix produces a poor stereo fold-down, then the complaints will come flooding in.

The best fold-down is produced by those systems that are coincident or near-coincident. The more widely spaced the array, the harder it is to get the two different mixes to correlate.

4. How do you choose?

This very much depends on circumstances. What am I covering? What is the programme content? How and where can I mount the microphones? Is it a fixed situation or will it be moveable? Is it for television or radio, or for producing a CD recording? If it's for television, will a particular array be too obvious "in shot" and what compromises will I have to make, to get a decent result?

What surround format am I going to use? 4.0/5.0/5.1 ... all the way up to 22.2 and beyond? What am I recording onto – multitrack, videotape with limited tracks, broadcasting live? Will there be any post-production involved? Is it a mixture of all of these?

The decision has to be based on training, experience, experimentation and, in the end, trial and error. And production colleagues have to be involved in the decision-making at the earliest possible moment. If they don't understand what is involved in what you are trying to attempt, you will find the whole process becoming an uphill struggle. Most production people know very little about Surround Sound and they need to be educated and encouraged to find out more – otherwise interest in Surround Sound from that quarter will wither away.

There are a host of techniques out there to learn and choose from, plus some of your own – given the time for thought, experimentation, practice and, last but not least, Trial and Error!

I was very fortunate in that I had used Dolby Surround at Wimbledon tennis for years before I was ever asked to do 5.1, and I had plenty of time to experiment without any pressure from anyone, other than myself!

Two programme examples

Wimbledon Centre Court

Audio coverage at Wimbledon for television was developed from early BBC Radio broadcasts, and started in the 1930s. The original style of tennis coverage was to place an omni mic on the chair for the effects, an omni over the umpire's head to hear the scores and, as a later addition, an omni mic above the crowd in the stands.

"Modern" mono coverage, starting from the late 1960s, consisted of a pair of shotgun mics looking into each side of the court from the umpire's chair, a switched cardioid mic for the umpire (also sent to the PA system) and a crowd mic (shotgun or omni depending on the venue) away from the action to keep prying ears away from anything the players at the chair might say to the Umpire. This is still the basic coverage for most tennis matches, with a little more attention being paid to what the players are saying to the Umpire!

In the 1980s, stereo coverage evolved to provide a fixed, stable, "one-end-of-the-court" image for the viewer. Ping-pong stereo, much beloved of hi-fi buffs at the time, was not considered the correct way to go!

Stereo started by using a well wind-proofed AKG C24 (set to cardioid) as a crossed pair but this was soon changed to an M+S system using a Neumann RSM 191. This was preferred because it was easier to mount in the venue, it was smaller in-shot and also gave better compatibility for viewers still listening in mono. This was in effect a hypercardioid and figure-of-eight combination.

Additionally, a stereo crowd mic was placed on a bar above the spectators, together with a camera giving a fixed-view, wide-angle shot of the court, which the mic matched perfectly. A net mic was added for "let calls" and for better coverage of the centre of the court during doubles matches. "Let calls" don't happen now but the mic remains for its effects contribution. A pair of courtside mics were added at either end of the base line for a little more crowd "intimacy" to bring home Wimbledon's unique atmosphere, the court itself being much smaller than it looks on television.

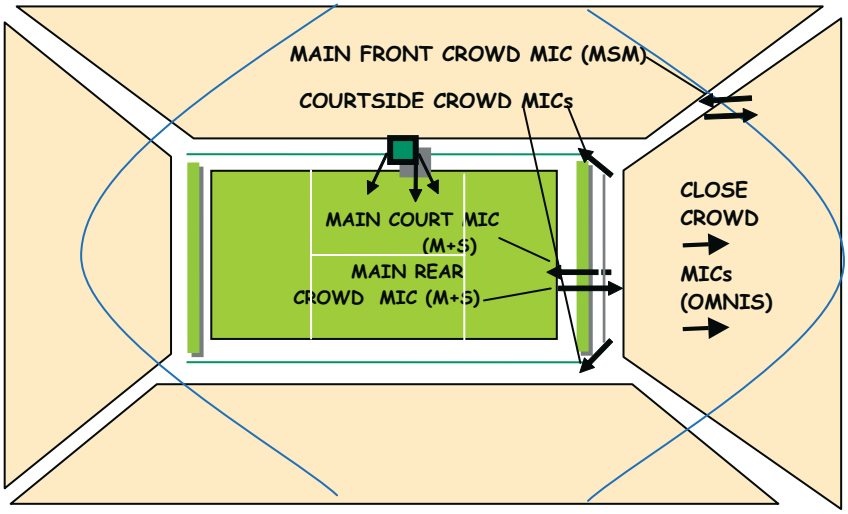


Figure 1
Position of the main Dolby 5.1 FX mics at Wimbledon

With the advent of Dolby Surround coverage, the rear channel offered a chance to involve the listener-viewer even more in "being in the crowd", even though the rear channel was only mono!

To this end, an additional single omni rear-crowd mic was placed up above with the stereo crowd mic, and some "close crowd" mics were placed in among the spectators for an even more realistic "in the middle of the crowd" experience, these three new mics being sent to the rear channel. The courtside pair were split and fed to both the front and rear of the mix to attempt to "join up" the front and back to give a smoother Surround effect. The front stereo coverage had progressed to an M+S setup using a Schoeps CCM cardioid and figure-of-eight system for better width coverage of the court and an even more discrete presence on court.

In spite of the limitations of the Dolby Surround format, the Surround effect proved to be very successful, and the time and effort taken to experiment and produce it were a very beneficial step towards producing further, more adventurous Surround mixes.

The current full 5.0 coverage adds a rear-facing M+S stereo pair (Cardioid) down at the court level (see *Fig. 1*) to provide the main rear crowd effects. Due to mounting constraints, this rear-facing microphone has to be mounted some 40 cms behind the forward-facing M+S pair facing the court and, in spite of initial worries about timing and phase issues, it has proved not to be a problem when folded down to stereo. The courtside mics are still fed to both front and rear channels to fill in the side "blank" that can be a feature of some Surround mixes. The close crowd mics are still used as a "spaced-pair". An MSM pair replaces the stereo and mono crowd mics in the Dolby Surround setup to give a high Surround crowd mic. There is no LFE channel produced, as there is little content at that low frequency worth broadcasting.

In effect my Surround array for Wimbledon acts like a very modified Fukada Tree.

My 5.0 Wimbledon coverage actually started as 4.0 as I didn't like using the Centre channel, especially for the court effects, as I felt it collapsed the stereo. However, I currently feed some of the commentary to the Centre channel (at about 8 dB lower than the L/R mix) just to give it some anchorage for viewers who might be outside the "sweet-spot" at home.

The stereo and Surround mixes are done on the same board. Previously, during the HD/5.1 trials in 2006, the stereo transmission to SD viewers travelled a completely separate path to that of the 5.1 mix for the HD viewers. The SD stereo mix was derived from the front of the 5.1 Surround mix and the metadata of the Dolby system adjusted so that no Surround or Centre channel contributed to the stereo fold-down on the HD service. This is because I wanted the stereo mix to be identical for both. This has now changed and, in future, the SD/stereo transmission will be derived from the HD/5.1 transmission automatically in the transmission suite, which means that, this year, I will have to

decide whether or not to include some of the Rear and Centre channels in the fold-down, using the Dolby metadata.

BBC Proms 2007/8

The basic microphone setup in the Royal Albert Hall for the Proms is designed and put in by BBC Radio and we, in Television Outside Broadcasts, add any additional microphones that we may want. The microphones used vary from day to day, depending on the orchestras and ensembles playing, hence the large number of microphones rigged for the season.

The system we used in 2007 was designed by my colleague Andy Payne and developed by trial and error over two years of recording the Last Night of the Proms for 5.1 post production, as well as his experiences recording opera in Surround at the Royal Opera House in London.

The sound field is split into three zones – the Stage, the Arena and the Space. The Stage zone uses a Decca Tree combined with two cardioid mics on the main bar pointing backwards and upwards. The Arena zone consists of an array of four Schoeps MK 4s, slung in the centre of the arena in a modified IRT Cross formation. The Space zone is made up of a pair of widely-spaced omni microphones set just below the dome and towards the rear of the Hall, combined with a pair of widely-spaced wide-cardioid mics set above the stage canopy.

Our production colleagues on the Proms are concerned about the quality of the stereo derived from the fold-down of the HD Surround mix, as this affects the majority of their viewers who watch and listen to the SD transmission. This has caused us to separate the stereo and Surround mixing areas into two different areas to enable us to create separate mixes for SD and HD. This has resulted in the main music-mixing truck providing Surround "stems" of the three zones. The Centre and LFE feeds, and separate soloists feeds if necessary, are sent to a second truck where the Surround mix is put together and any in-vision links and interviews added. The stereo mix is then made in the main music truck during the actual performance and passed to the second truck where the same links and interviews are added, the two mixes taking separate paths out to air.

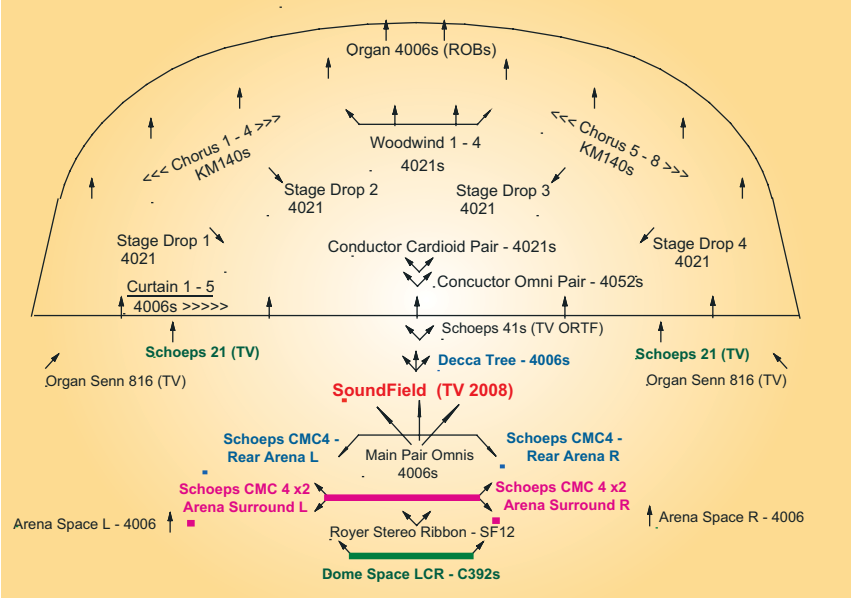


Figure 2
The Proms 2008 mic layout at the Royal Albert Hall, London

This is an expensive and ultimately redundant way of operating. It is redundant because, from this year on, the SD pictures and stereo sound will be derived from the HD pictures and Surround mix, so there will be no opportunity to transmit a separate stereo mix for SD viewers.

This year (2008) we are hoping to rig a SoundField microphone in the Hall for the duration of the Proms. As mentioned above, this microphone's Surround output is referenced to a single point giving extremely good stereo and mono compatibility. Hopefully this will fully address our production colleagues' fears, as well as simplifying the whole process.

Bill Whiston joined BBC Television in September 1970 and BBC Outside Broadcasts in 1978. He has been involved in a whole range of different types of programmes, covering all aspects of Outside Broadcast's output, from major events such as the Queen's Golden Jubilee celebrations for which he won a Royal Television Society Award, to Sport, including fifteen years mixing Centre Court at Wimbledon, where he first became involved in Surround mixing, and two Olympics Tennis events, in Atlanta in 1996 and Athens in 2004.

Mr Whiston have been involved in major BBC Drama productions over many years, including the first live drama transmitted on the BBC for twenty years when they produced "Quatermass" from a location just outside London in April 2005 which was also recorded for Surround post production. In recent years he has regularly balanced a number of BBC Promenade Concerts from the Royal Albert Hall for both BBC1 and BBC2. He has also mixed a wide variety of programmes, both in the UK and abroad, including the Handover of Hong Kong to China, live interactive natural history programmes from the Rift Valley to schools across the United States and the UK, religious programmes from Jordan and a documentary series on aircraft from France and the USA.

Summary

Each of the programmes discussed above has its own particular problems. Because I have been mixing Wimbledon in Surround for so long, it has pretty much settled as a concept, although that's not to say that changes and challenges don't come along every year. I was lucky enough to have had the freedom and time to think, invent and play with it before anyone became aware of what I was doing.

The Proms is a very different proposition, relatively recent in design and with little or no time allocated to think about or modify the system, to try different arrays. In this situation one needs to multitrack the microphones and spend time after the event practising. Productions are reluctant to spend money this way but, in a large organization, this is exactly what the training budget should be used for. Problems and techniques will only be resolved and formulated by practice and reflection.

Practitioners need to talk to producers. They need to understand what's involved, what are the problems and, most of all, what are the benefits that Surround Sound brings to their programmes.

There should be time for discussion, experimentation, practice and trial and error!

... It's the only way.

And so, where to start?

- Start from stereo and add to that.
- You don't have to reinvent the wheel. Use any of the techniques available as a start. Experience and practicality will create change.
- There doesn't have to be something in ALL the channels ALL the time.
- 4.0 can work just as well as 5.0 or 5.1.
- Do whatever suits the subject. Make it as natural as possible unless you are after a specific effect, and above all ...
- **Use your ears!**