Audio Engineering Society

Convention Paper 9186

Presented at the 137th Convention
2014 October 9–12 Los Angeles, USA

Downward Compatibility Configurations when using a univalent 12 Channel 3D Microphone Array Design as a Master Recording Array.

Michael Williams[1][1]

[1] Sounds of Scotland, Le Perreux sur Marne, 94170, France

ABSTRACT

It can be shown that Microphone Array Design applied to a 12 Channel 3D Microphone Array can create a Master Recording Array design that will generate downward compatible channel signals that satisfy most of the present-day univalent lower order channel/loudspeaker configurations. The implementation of this compatibility oriented array design requires no matrixing or processing of the channel signals, whilst still maintaining the integrity of the overall sound field architecture. This compatibility approach, to 3D array design, produces a master recording system that can be adopted for overall production, eventually to be distributed using several different media formats (stereo, DVD, Blu-ray, 3D, etc.). However this approach can also be used as a consumer choice function within a global master recording or file downloading facility.

1. INTRODUCTION

The 12 channel 3D microphone array design, shown in Figure 1, is based on the isosceles triangle structure as developed in a paper presented at the recent AES Rome Convention (Preprint 8839) **(1)** .

This type of array has proved capable of producing a realistic and robust 3D sound field. If we adopt a minimalistic approach to the number of channels needed in reproduction within lower order configurations, it is obvious that there is a certain amount of redundancy in the overall 12 channel array. However this is consistent with the aim of maintaining complete compatibility of the overall master recording array with most of the present-day lower-order/channel reproduction systems.

Standard reproduction systems using 2 channels (Stereo), 4 channels (Quadraphony), 5 channels (so called multichannel), 7 channels (Blu-ray), 8 channels (Octophony) or the 3D reproduction formats, are directly compatible with the 12 channel 3D array, without any mixing or matrixing – only the selection of the specific channels is required.

1.

FIGURE 1 –THE 12 CHANNEL 3D MICROPHONE ARRAY DESIGN

The basic compatibility configurations for the 8 channel M.A.G.I.C. system were presented at the 122nd AES Convention in Vienna (Preprint 7057) [(2)]. The present paper will concentrate on the new array configurations introduced by the 2nd layer of 4 microphones for height reproduction.

An intriguing set of configurations, which combine both 3D reproduction, and compatibility with 2D-reproduction, was presented to three different panels of listeners for their comments. The loudspeaker configuration was the same in each of the listening contexts and is shown in Figures 2, 3, 4 & 5.

FIGURE 2 – 12 CHANNEL LOUDSPEAKER CONFIGURATION
ITEMM – LE MANS, FRANCE

FIGURE 3 – 12 CHANNEL LOUDSPEAKER CONFIGURATIONS
(NSEW AND AURO 3D) – GALAXY STUDIOS, MOL, BELGIUM

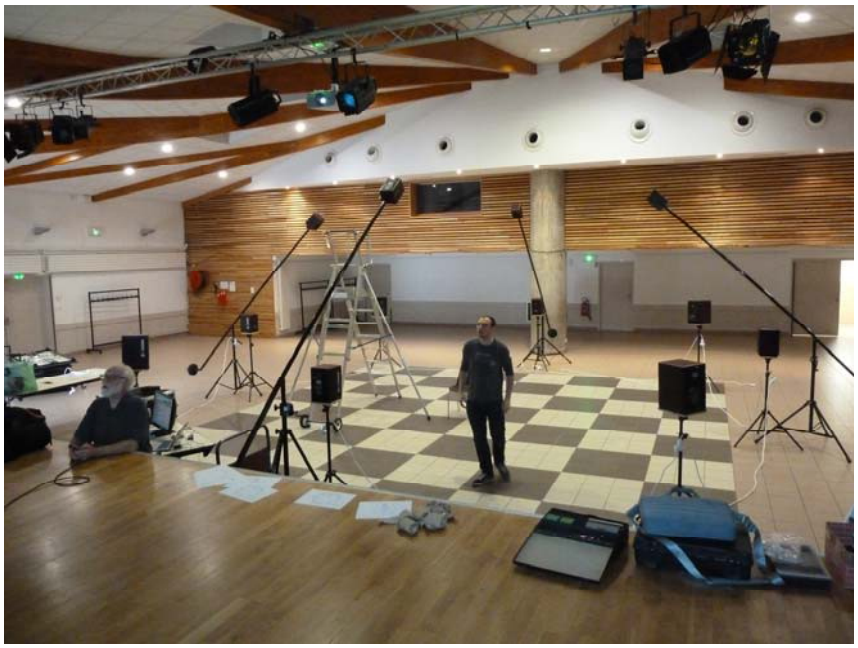

FIGURE 4 – 12 CHANNEL LOUDSPEAKER INSTALLATION
AES FRENCH SECTION MEETING – LYON, FRANCE

FIGURE 5 – THE FINAL CHECK BEFORE THE AES FRENCH SECTION MEETING LYON, FRANCE

Figure 3 is slightly different from the other venue configurations in that two reproduction formats were compared – NSEW (height loudspeakers at N - 0°, S - 180°, E - 90° and W - 270°) and Auro 3D (height loudspeakers at 45°, 135°, 225° and 315°). Figure 4 shows the height loudspeakers in the process of installation. In Figure 5 we can see the final position of the loudspeakers after they have been winched up to the correct height. The height loudspeakers are normally positioned so that they make an angle of 45° with the horizontal plane.

2. COMPATIBILITY

2.1 Full Compatibility and Redundancy

The 1st layer of the 8 microphone array (the M.A.G.I.C. array)[2] was coupled with the 2nd layer of 4 microphones in a spaced quad structure at 0°, 180°, 90° and 270°, and 55cm spacing. It was found that the satellite microphones (Center, Left Median, Right Median and Back) in the first layer were quasi redundant, and for most listeners the only difference detected between the full 12 channel reproduction and an 8 channel reproduction (i.e. without the satellite microphones of the lower layer) was a slight decrease in the bass response of the system when only the 8 channels were active. It must be said however that the full 12 channel array is necessary, if full downwards compatibility is to be maintained.

2.2 Reducing the Toroïdal Ring[3] Wave Front Propagation below the Aliasing Frequency

This difference in bass response, with or without the satellite microphones, has been identified as being associated with the change, at the so called aliasing frequency, from individual loudspeaker spherical wave propagation (shown in Figure 6) to the combined loudspeaker toroïdal ring radiation pattern (shown in Figures 7 & 8). In the first case (above the aliasing frequency) we obtain the standard stereo virtual image generation with total spherical wave front propagation from each loudspeaker. Whereas in the second case, below the aliasing frequency, the radiation from each loudspeaker combines with the adjacent loudspeaker to produce one continuous spherical wave front in the horizontal plane, the inside surface of a torus ring focusing onto the listener. Thereby gradually increasing the amplitude response in the bass frequencies. The aliasing frequency is determined by the distance between adjacent loudspeakers. When it is possible to position the horizontal plane loudspeakers on the circumference of a large circle (a diameter of 10 to 20 metres), the aliasing frequency is low down in the audible spectrum (approximately 40HZ to 20Hz respectively). In this situation the increase in bass response can almost go undetected.

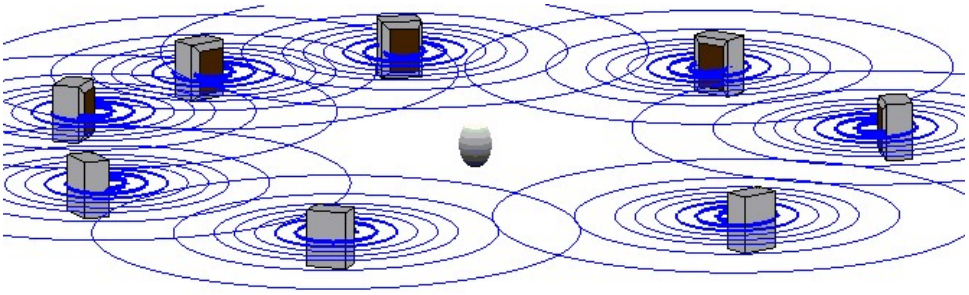

FIGURE 6 – ABOVE THE ALIASING FREQUENCY
INDIVIDUAL LOUDSPEAKER SPHERICAL WAVE FRONT PROPAGATION

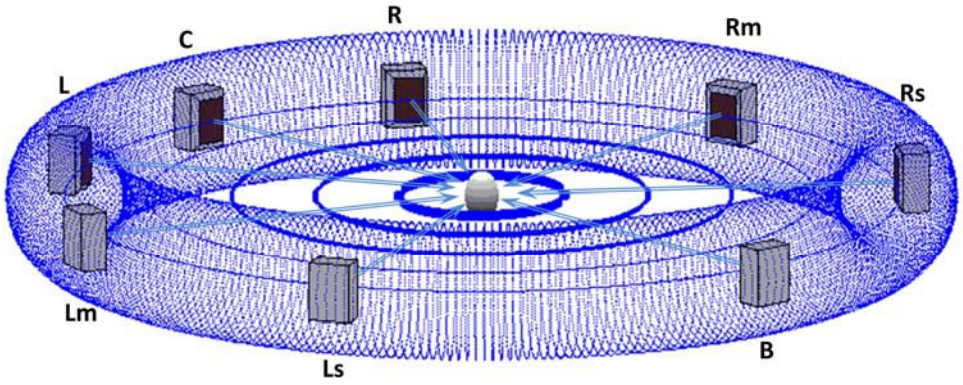

FIGURE 8 – BELOW THE ALIASING FREQUENCY
COUPLED LOUDSPEAKER TOROÏDAL RING WAVE FRONT PROPAGATION

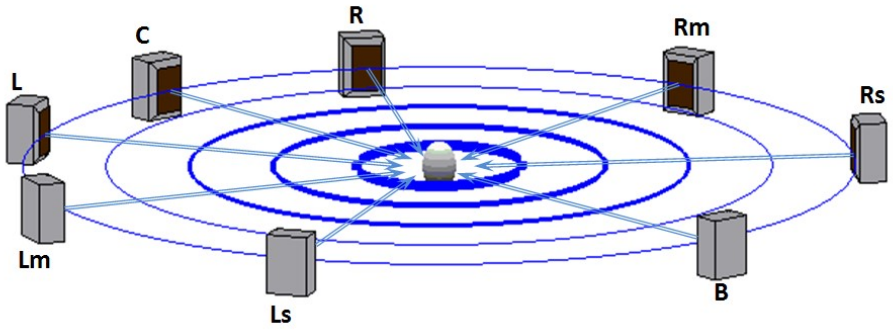

FIGURE 8 – BELOW THE ALIASING FREQUENCY
COUPLED LOUDSPEAKER TOROÏDAL RING WAVE FRONT PROPAGATION
IN THE HORIZONTAL PLANE TOWARDS THE LISTENER

This effect is considerably reduced by the use of cardioid microphones as satellite microphones (C, Lm, Rm & B), thereby decreasing both the coupling between loudspeakers and therefore also reducing the toroïdal ring wave front propagation of the lower 8 channel array in the bass frequencies. This means that the difference between the full 12 channel reproduction (as shown in Figure 16), and the 8 channel (4 + 4) reproduction (as shown in Figure 17) is, in practice, negligible. This has considerable advantages in the design of a more compact 3D/2D array, using the Left, Right, Left Surround and Right Surround microphones of the horizontal plane array, and the Height Centre, Height Right, Back and Height Left microphones of the 2nd layer (at 0°, 90°, 180° and 270° respectively).

2.3 Compatibility of the 4 + 4 3D array with the 4 + 4 2D array

Another compatibility comparison was presented in the listening tests, using an 8 channel 2D reproduction loudspeaker array, but routing the four 2nd layer (height) microphones (Hc, Hr, Hb & Hl) to the center, right median, back and left median loudspeaker channels in the horizontal plane (as shown in Figure 18). This is tantamount to considering that the four height channels, in the 4 + 4 array, can replace the satellite microphones in the 8 channel M.A.G.I.C. array. The surprising result was that this caused little change in the general sound field architecture, as long as the change from 3D to 2D reproduction was taken into account.

In fact we can trace this projection approach back to some pioneering work done by two sound recording engineers at Radio France in the late 1970s[(4)]. Madelaine Sola and Daniel Torsière, working within the structure of the 'Atelier de Recherche Techniques' at Radio France, developed a system which they called 'Hexaphonie' This six channel surround sound system consisted of two layers of Schoeps cardioid microphones (MK5), each layer being a triangle of microphones at 120° to each other (as shown in Figure 9). The spacing between microphones was 35cm and the two layers were positioned so as to create equilateral triangles between the lower and upper layer of microphones. Each microphone signal was then routed towards its corresponding loudspeaker in a univalent horizontal circular array of six loudspeakers in an equal segment configuration.

FIGURE 9 – 'HEXAPHONIE' ARRAY (ORIGINAL PHOTO BY ROGER PICARD) RADIO FRANCE

3. LISTENING TESTS

3.1 Listening Test Venues

The comparison between all the different compatibility combinations was presented in three different listening venues, and to three different set of listeners.

1. A specialist listening panel at the University of Gothenberg, Sweden – the GOArt project [(4)].
2. At a French Section meeting in Lyon, France
3. And at a course on 2D and 3D recording and reproduction for 2nd year students at the ITEMM in Le Mans, France

3.2 Listening Test Procedure

A special channel switching system, controlled by ProTools, allowed the listeners to compare, in real time, the various reproduction configurations that were being demonstrated

1. Front sound stage reproduction in stereo or triphony
2. Single layer surround sound reproduction compared with the two layer 3D reproduction
3. Four channels in the lower layer + four 2nd layer channels reproduction, compared with the full 12 channel (2 layer) 3D reproduction
4. Four (1st layer) + four (2nd layer) 3D reproduction compared with the surround sound system created by projecting the four by four reproduction height channels into the Ssatellite channels of the eight channel horizontal system.

All the comparison pairs were generated by rapid cross-fading between two specific configurations, thereby allowing the listener to make a quality assessment in the crucial few seconds around the cross-over.

3.3 Recordings Presented

At the 1st venue only locally recorded organ music was presented. At the 2nd and 3rd venue, the recordings included an extract from the 'Jardin de Haikus' by Ramon Humet played by the London Sinfonietta and recorded at the Watford Colosseum in London, an extract from 'Ach wie nichtig, ach wie flüchtig' by George Böhm recorded at the 'Ôrgate Nya Kyrka' in Gothenberg, a clarinette trio recorded at the Montesquieu Church in Le Mans in France, some small ensemble classical recordings recorded in Barcelona, and a spectacular recording made at the last RAF Airshow at Leuchars in Scotland, as well as recordings of some animal sounds. Some recordings were also presented illustrating the first stage towards a new 12

3.4 Analysis

The complete set of loudspeaker configurations, that were tested for compatibility, are shown in Figures 10 to Figure 18.

It must be said initially that there was of course no intention to say or imply that the signals derived for, let us say, stereo reproduction will produce a surround sound impression, and that signals derived for surround sound reproduction will produce any form of height information. The intention of these listening tests was however to show how this type of microphone array system will produce signals that will be entirely satisfactory in stereo reproduction, and to compare this stereo reproduction with for instance 3 channel 'Triphony' for front sound stage recording and reproduction. The microphone array system also produces signals that will create satisfactory surround sound in any of the present 'state of the art' reproduction formats (for instance quadraphony, multichannel 5.1 or Blu-ray 7.1). The same microphone array is also capable of generating signals for the emerging 3D formats.

In each of these categories the acoustic architecture is maintained in each of the various formats, whilst extra dimensions of sound reproduction are of course introduced in the migration from stereo to surround sound to 3D.

In the 1st group of listening tests in Gothenberg, the listeners were not even conscious that they were listening to either 12 channel 3D system or an 8 channel 3D system. This suggests that there is almost total compatibility between the two reproduction systems.

In group 2 and group 3 - the same excellent compatibility was experienced in the comparison between each of the 4 categories:

1. Front sound stage reproduction with 2 channel stereo and 3 channel triphony. The 3 channel system did show better geometric localization linearity compared to the 2 channel stereo due to the improvement in the linearity coeficient with Triphony.
2. The different surround sound formats – 4 channel quadraphony, 5 channel multichannel, and 7 channel Bu-ray were deemed similar but with improving linearity again with the increase in the number of channels. This was especialy evident in the change from 5 channel multichal to 7 channel Blu-ray format. The reproduction with 8 channels (addition of the 'back' loudspeaker,
3. The addition of height information produced a realistic and robust sound field. The change from 4 + 4 reproduction to 8 + 4 reproduction was almost imperceptible.
4. The change from 4 + 4 3D reproduction to an 8 channel surround sound reproduction showed that the 3D reproduction could be successfully projected onto the surround sound reproduction field without modifying the overall sound field architecture.

In other words the objectives in developing this type of array were completely satisfied. This type of channel based reproduction is, of course, 'sweet spot' dependent, and only a WFS virtual loudspeaker reproduction system can give a wider listening base.

For many people participating in these listening sessions, this was their first exposure to 3D sound recording and reproduction techniques, and gave rise to some very interesting discussion on the subject.

4. STANDARD AUDIO MEDIA VERSUS FILE DOWNLOADING

The rapid evolution of the reproduction environment is forcing the production process to take into account many different reproduction formats - it is no longer really viable to produce for a single media support. In fact we are already seeing the possibility of purchasing or downloading audio files of a specific product in a few of

the different reproduction formats. The compatible microphone array recording system directly allows downloading of only the required channels for a specific reproduction format by the consumer, without any complex rematrixing or processing - updating of previous downloads to more advanced formats being simply a matter of adding the additional channels.

There must also be a considerable change in the audio industry sound recording practices for this inter-channel compatibility characteristic to be available on all the marketed audio products.

5. LOUDSPEAKER CONFIGURATIONS

Figures 10 to 15 show the complete set of compatible configurations within the 8 Channel M.A.G.I.C. Recording Array and its reproduction setup. Whereas Figures 16 to 18 show the new 3D/12 Channel compatible loudspeaker configurations.

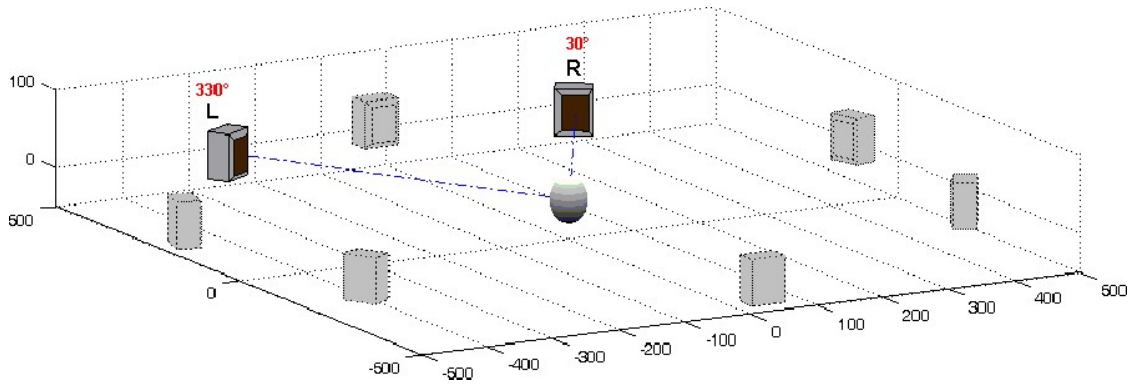

FIGURE 10 – STEREO LOUDSPEAKER CONFIGURATION
LEFT AND RIGHT LOUDSPEAKERS ARE ACTIVE,
CENTRE, LM, RM, LS, RS AND BACK LOUDSPEAKERS ARE ALL MUTED

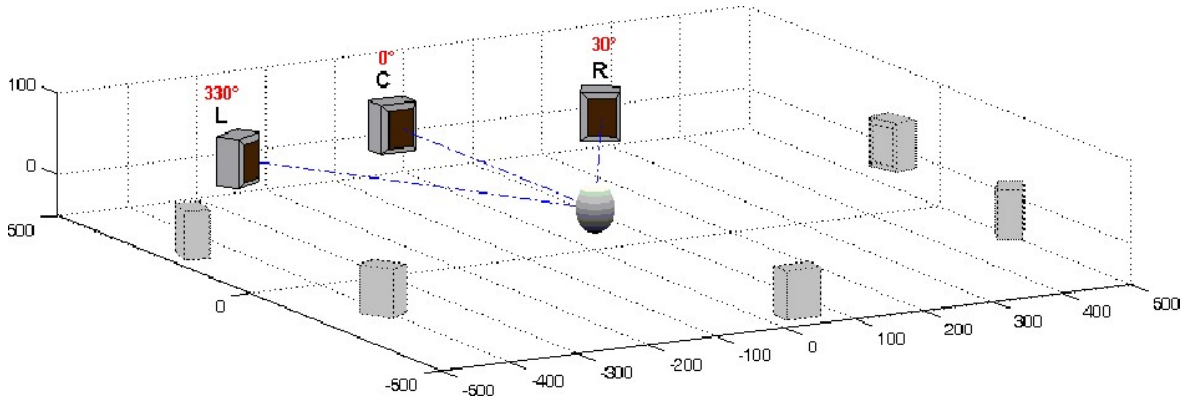

FIGURE 11 – 3 CHANNEL (TRIPHONY) LOUDSPEAKER CONFIGURATION
LEFT, CENTRE AND RIGHT LOUDSPEAKERS ARE ACTIVE,
LM, RM, LS, RS AND BACK LOUDSPEAKERS ARE ALL MUTED.

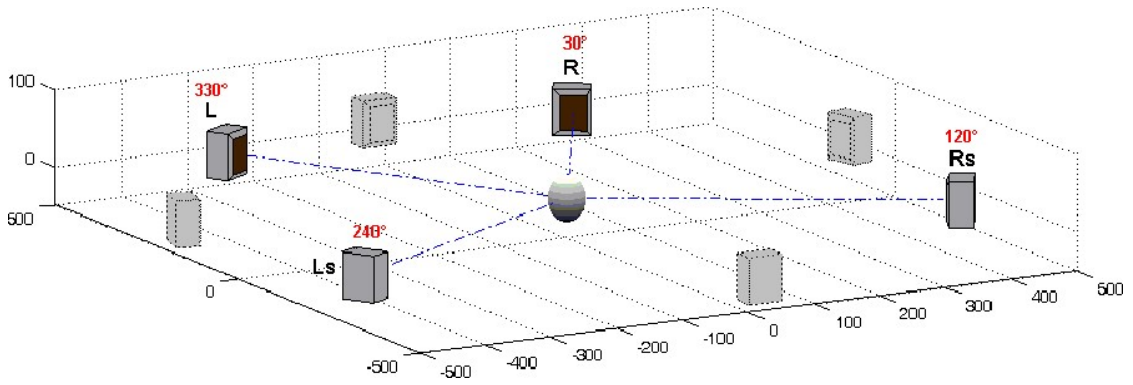

FIGURE 12 – 4 CHANNEL (QUADRAPHONY) LOUDSPEAKER CONFIGURATION
LEFT, RIGHT, LS AND RS LOUDSPEAKERS ARE ACTIVE,
CENTRE, LM, RM, AND BACK LOUDSPEAKERS ARE MUTED.

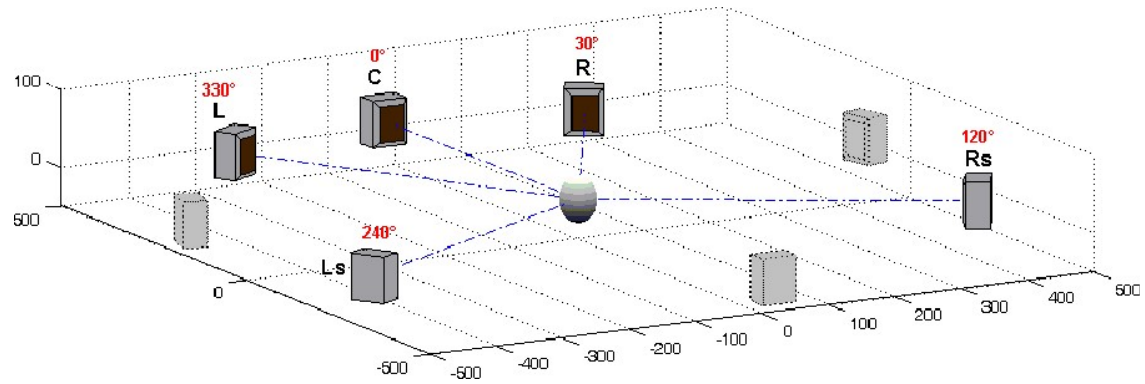

FIGURE 13 – 5 CHANNEL (MULTICHANNEL) LOUDSPEAKER CONFIGURATION
CENTRE, LEFT, RIGHT, LS AND RS LOUDSPEAKERS ARE ACTIVE,
LM, RM, AND BACK LOUDSPEAKERS ARE MUTED

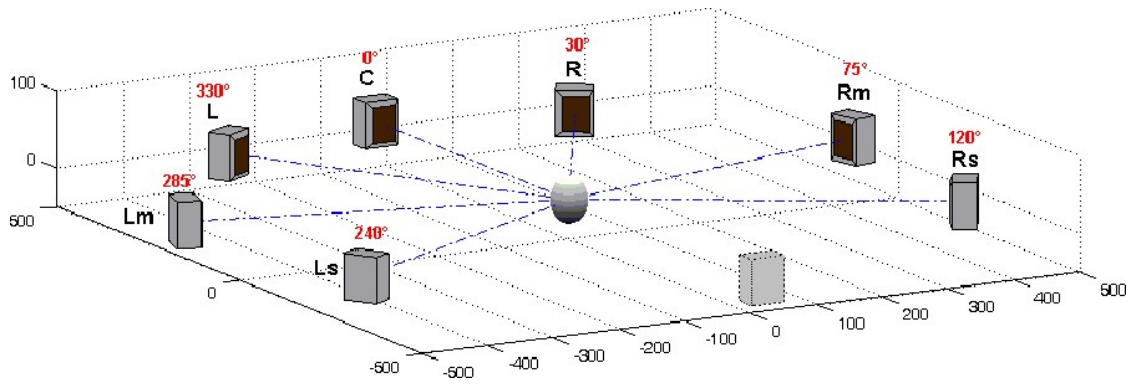

FIGURE 14 –7 CHANNEL (BLU-RAY) LOUDSPEAKER CONFIGURATION
CENTRE, LEFT, RIGHT, LM,RM, LS AND RS LOUDSPEAKERS ARE ACTIVE,
BACK LOUDSPEAKER IS MUTED.

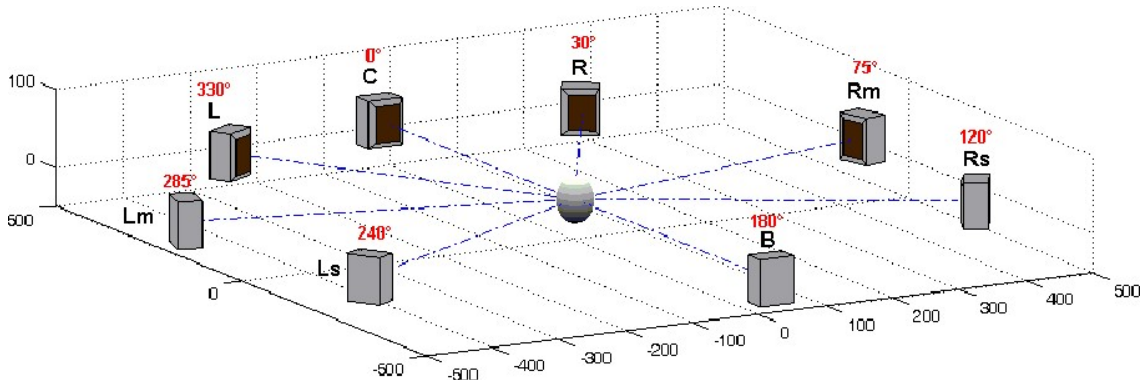

FIGURE 15 – 8 CHANNEL(OCTOPHONY) LOUDSPEAKER CONFIGURATION
ALL LOUDSPEAKERS ARE ACTIVE.

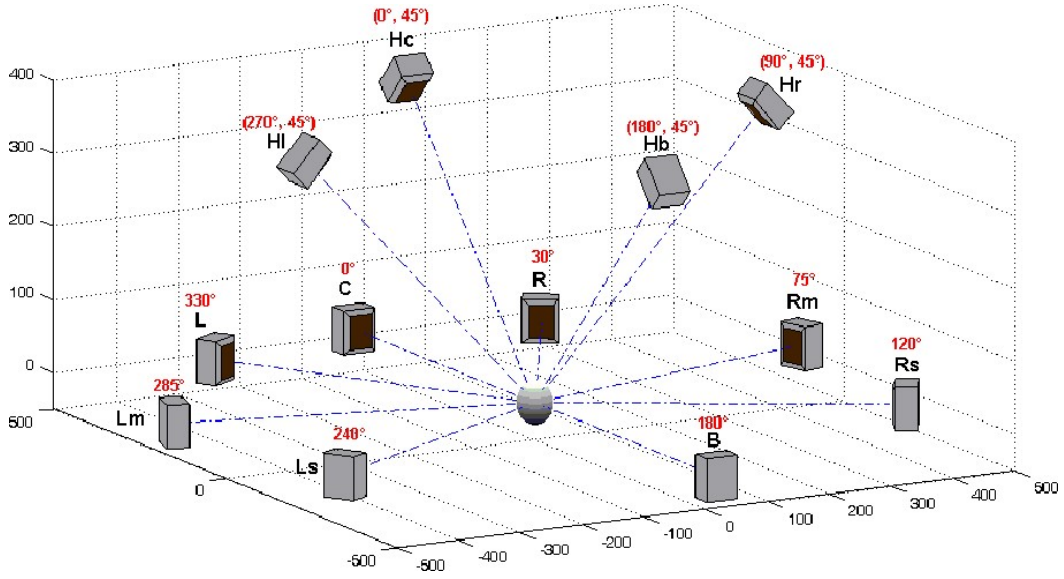

FIGURE 16 – FULL 12 CHANNEL LOUDSPEAKER CONFIGURATION
ALL LOUDSPEAKERS ARE ACTIVE.

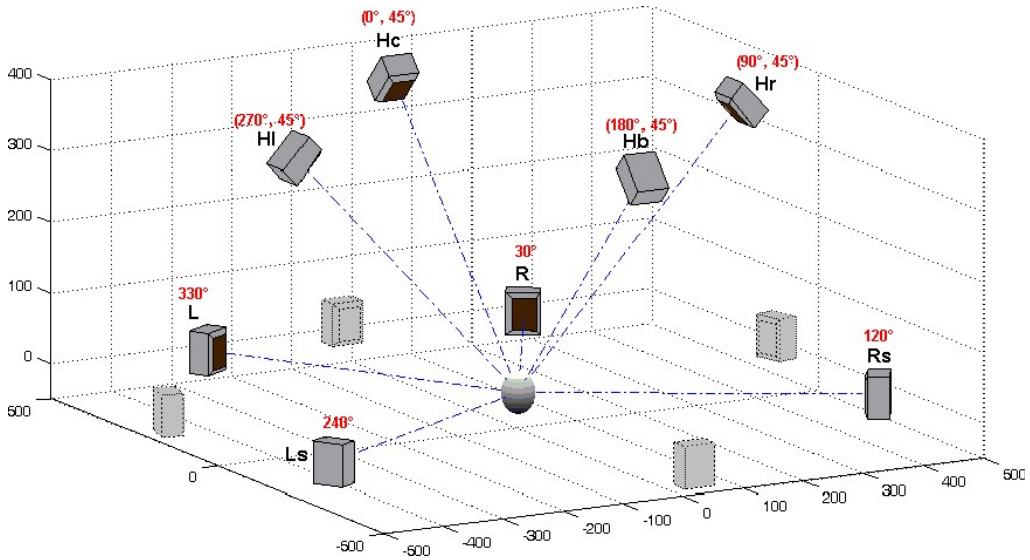

FIGURE 17 – 4 + 4 CHANNEL LOUDSPEAKER CONFIGURATION
LEFT, RIGHT, LS, RS, HC, HL, HR AND HB LOUDSPEAKERS ARE ACTIVE,
CENTRE, LM, RM AND BACK ARE MUTED

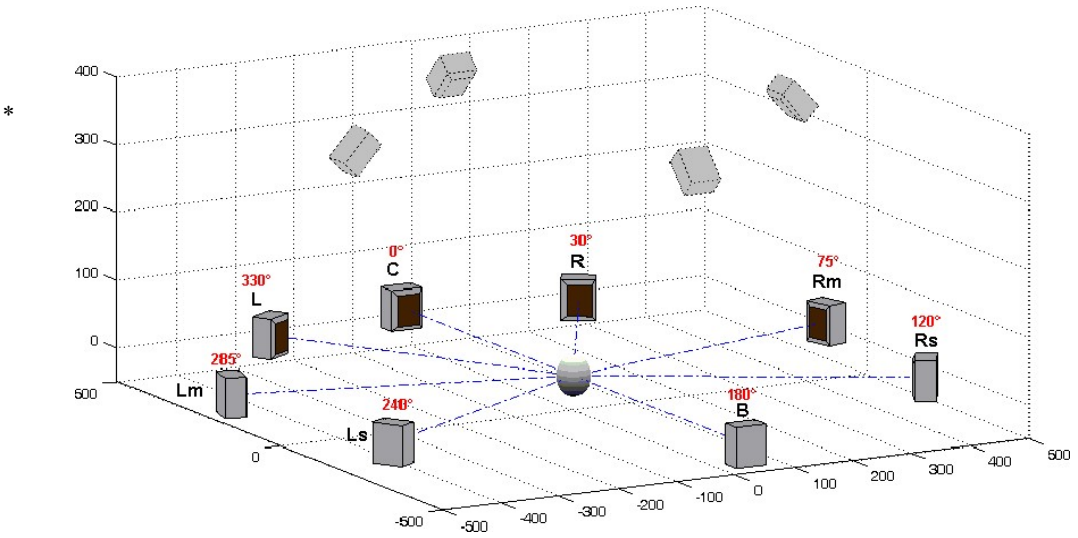

FIGURE 18 – '4 + 4' HORIZONTAL CHANNEL LOUDSPEAKER CONFIGURATION
CENTRE, LEFT, RIGHT, LM, RM, LS, RS AND BACK, LOUDSPEAKERS ARE ALL ACTIVE,

SIGNALS FOR HC, HL, HR AND HB ARE FOLDED INTO
CENTRE, LM, RM AND BACK LOUDSPEAKERS RESPECTIVELY

6. ACKNOWLEDGEMENTS

'Remerciements' to Lilian Dufrechou, 'Formateur and Responsible de Formation Son' at the ITEMM (Institut technologique euopéen des métiers de la musique), and to the 2nd year students (2013) at the ITEMM studying for the title of 'Régisseur son du spectacle vivant ou de la production multimédia'.

Thanks are also due to Wilfried van Baelen, CEO of Auro Technologies and Galaxy Studios, for giving me access to some wonderful studio and listening room facilities at Galaxy Studios and participating also in the listening tests.

Thanks also to Jean Francois Bau, who organised the AES French Section meeting at the Tabagnon Center near Lyon. This meeting was organized in collaboration with the GRAME (Centre Nationale de Création Musicale) and the IMAGINOVE (Pôle de compétitivité/ cluster des filières des contenus numériques -jeu vidéo, cinéma, audiovisuel, animation et multimédia).

7. REFERENCES

1) 'The Psychoacoustic Testing of the 3D Multiformat Microphone Array Design, and the Basic Isosceles Triangle Structure of the Array and the Loudspeaker Reproduction Configuration' by Michael Williams - *134th AES Convention in Rome (preprint 8839)*

2) 'Magic Arrays - Multichannel Microphone Array Design applied to Multi-format Compatibility' by Michael Williams - *122nd AES Convention in Vienna (Preprint 7057)*

3) Weisstein, Eric W. "Ring Torus" from MathWorld - A Wolfram Web Resource. http://mathworld.wolfram.com/RingTorus.html

4) 'Hexaphonie' by Madelaine Sola and Daniel Torsière – document published by the Press Office of Radio France as a hand-out during a demonstration of 'Stéréophonie, Tetraphonie and Hexaphonie' at Radio France on the 28 May 1979.

5) 'A 3D and Multiformat Microphone Array Design for the GOArt Project - 'The Organ as a Memory Bank' by Michael Williams - *presented at the 27th Tonmeistertagung in Köln in 2012*