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The Psychoacoustic Testing of the 3D Multiformat Microphone Array Design, and the Basic Isosceles Triangle Structure of the Array and the Loudspeaker Reproduction Configuration.

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ABSTRACT

Optimizing the loudspeaker configuration for 3D Microphone Array Design can only be achieved with a clear knowledge of the psychoacoustic parameters of reproduction of height localization. Unfortunately HRTF characteristics do not seem to give us useful information when applied to loudspeaker reproduction. A set of psychoacoustic parameters have to be measured for different configurations in order to design an efficient microphone array recording system, even more so, if a minimalistic approach to array design is going to be a prime objective. In particular the position of a second layer of loudspeakers with respect to the primary horizontal layer is of fundamental importance, and can only be based on the psychoacoustics of height perception. What are the localization characteristics between two loudspeakers situated in each of the two layers? Is time difference as against level difference a better approach to interlayer localization? This paper will try to answer these questions and also justify the basic isosceles triangle loudspeaker structure that will help to optimize the reproduction of height information.

1. INTRODUCTION

The first layer of the 12 channel 3D Multiformat microphone array is based on the 8 channel M.A.G.I.C. Microphone array and loudspeaker configuration presented at the 122nd and 124th AES Conventions in Vienna and Amsterdam [1][2]. The introduction of an additional 2nd layer of microphones to the M.A.G.I.C system, and the corresponding loudspeakers in reproduction, introduces natural physical vertical localization sound sources and therefore gives the potential for some height localization. The main question to be answered is:

'Can we expect virtual localization between loudspeakers to fulfill the role of creating reliable height localization and therefore, with the complete configuration of loudspeakers, to produce robust 3 dimensional space reproduction'.

In this present paper, a clear distinction must be made between the series of listening tests used to understand the psychoacoustics of height perception when using loudspeaker reproduction , and an additional series of psychoacoustic tests which were designed specifically to verify some of the reproduction characteristics of the experimental 12 channel 3D Multiformat Microphone Array configuration

The basic design of the 12 channel 3D Multiformat Array was initially tested in a series of recordings of contempory music in the Watford Colosseum in London, and of organ music in Göteborg. Some difficulty in vertical localization was experienced when certain loudspeakers were mounted one above the other. It was considered probable that localization from diagonal pairs of loudspeakers would be projected only onto the horizontal plane and not in the vertical plane. Careful psychoacoustic testing of vertical and diagonal localization did not confirm this hypothesis, but it did bring to light an unexpected result – that very good localization was only produced on the DIAGONALS between 1st layer and 2nd layer loudspeakers.

Initial test signal recordings were made in the anechoic chamber in the Division of Applied Acoustics, Chalmers University of Technology, Göteborg. A series of combined Level and Time Difference signals were generated using a standard horizontal microphone pair (25cm/90° cardioids), the sound source moving around the microphone pair in the horizontal plane. Afterwards, in the listening tests, the two signals were routed to either just the vertical pair of loudspeakers or to just a diagonal pair of loudspeakers.

NO PRECISE LOCALISATION was experienced in the vertical plane, however very precise localization WAS observed along the diagonal plane. In the first case this confirmed what was expected (and presented at the 132nd Convention in Budapest [3]), whereas the second case was a complete surprise. In the second case localization was expected to be projected onto the horizontal plane with no vertical component, but in reality the localization followed the line between the diagonal loudspeakers and was a clear and realistic reproduction of the sound source.

This means that we can expect no reliable sound source localization between loudspeakers that are situated vertically one above the other, but that loudspeakers placed in an isosceles triangle structure around the listener, will produce reliable virtual localization of sound images. Of course, for optimum reproduction quality, the loudspeaker structure must be the mirror image of the microphone array structure. But this does not mean that the microphones have to be in exactly the same orientation as the loudspeakers, but the general univalent triangular structure must be the same.

A second series of tests was designed to test whether Level-Difference, Time Difference or a combined Level and Time Difference signal would affect the localization characteristics in various diagonal configurations.

2. DIAGONAL LOCALISATION TESTING SIGNALS

The height loudspeaker was positioned above the center at 45° elevation, loudspeakers pairs were tested using four specific configurations:

a) The 1st Layer Loudspeaker was in the center (the loudspeakers are therefore one above the other).
b) The 1st layer loudspeaker is still in the horizontal plane, but at 10° to the center
c) The 1st layer loudspeaker is still in the horizontal plane, but at 20° to the center
d) The 1st layer loudspeaker is still in the horizontal plane, but at 30° to the center

Four test signals were used

a) The initial anechoic room recording using a Hybrid pair - 25cm/90° cardioids
b) A studio recording using a Level-Difference-only pair – 0cm/160° cardioids
c) A studio recording using a Hybrid pair – 25cm 90° cardioids
d) A studio recording using a Time-Difference-only pair – 50cm/0° cardioids

All the microphone pairs used to generate the test signals were designed to maintain the same stereophonic recording angle of +/- 50°.

The anechoic recordings were made at the Division of Applied Acoustics, Chalmers University of Technology, Göteborg. The studio recordings were made at Galaxy studios in Belgium.

The Hybrid pair was chosen specifically to be the same in both the studio and the anechoic recordings.

The Time Difference only pair was designed using specifically cardioid microphones, so as to be sure that timbre differences would not interfere with the listening tests. Spaced microphone recording techniques usually use omnidirectional microphones, but this introduces very definite spectral differences between the cardioid and the omnidirectional test signals. Using parallel cardioid microphones on the other hand maintains the same timbre in all the test signals.

3. TESTING THE 2ND LAYER SOUND CATCHMENT AND THE ACOUSTIC LAYER SWITCH MECHANISM

Additional test recordings were also made with a spaced pair configuration using a cardioid microphone and a figure of eight microphone, with 90° between the axes of directivity and 100cm between the capsules. Test recordings were also made using a spaced (50cm) parallel pair of figure of eights. These two specific pair configurations correspond to different parts of the total 12 channel 3D Multiformat array configuration – the side sound catchment and the top sound catchment.

4. LISTENING TEST LOCATIONS

Listening test were carried out in four locations

a) At the Division of Applied Acoustics, Chalmers University of Technology, Göteborg, Sweden.
b) At Galaxy Studios in Mol, Belgium
c) At the ITEMM (Institut Technologique Européen des Metiers de la Musique) in Le Mans, France
d) At the INA (Institut National de l'Audiovisuel) in Bry sur Marne, France.

It must be emphasized that these listening test were basically for qualitative testing, rather than quantitative testing. In other words they were designed to verify the nature of the localization characteristics rather than make a specific mapping of the exact localization in each case.

5. THE 12 CHANNEL 3D MULTIFORMAT ARRAY MUSIC AND AMBIENCE RECORDINGS

Apart from the test signals generated specifically to test certain parameters of localization, a series of 12 channel 3D Multiformat Array music and

natural ambience recordings were presented at each of the listening test venues.
These recordings were as follows:

a) Extract from the Jardin de Haikus (for Violin, Cello, Piano and 3 Percussion) by Ramon Humet performed by the London Sinfonietta in the Watford Colosseum in London in January 2012.
b) Extract from Ach wie nichtig, ach wie flüchtig Chorale Arbeit – 8 variations by Georg Böhm the Ôrgryte Nya Kyrka (Organist – Joel Speerstra – August 2012) in Göteborg, Sweden.
c) Natural ambience sound recordings – Concerto in E# for Helicopter & Barge in Warm Weather - with the *Natural Habitat Environmental Orchestra*, Ile du Moulin, near Paris, France
d) The Mozart Divertimento No1 in D maj (Menuetto and Allegro), K136, played by a clarinette trio of students from the CRD du Mans (Conservatoire à rayonnement départemental du Mans) recorded at the 'Chapelle de l'Oratoire, at the Lycée Montesquieu' in Le Mans in February 2013..

In Göteborg and at Galaxy we were able to listen to 'a', 'b' and 'c'.

At the ITEMM and the INA we were able to listen to all the recorded examples.

The INA listening tests also corresponded with the INA Open Day which resulted in about 60 people being able to listen to excerpts from 'c' and 'd'.

6. GENERAL ANALYSIS OF THE RESULTS OF LISTENING TEST USING THE DIAGONAL LOCALIZATION TESTING SIGNALS

a) The results concerning virtual localization obtained using test signals recorded in an anechoic room and in a studio environment were indistinguishable.
b) No virtual localization (localization between loudspeakers) was experienced when the loudspeakers were placed one above the other. This was confirmed for the three types of test signal (Level Difference only, Time Difference only and Hybrid)
c) Virtual localization improved immediately when a diagonal loudspeaker position component was introduced. Localization precision improved as the diagonal angle between loudspeakers was increased (from 10° to 20° to 30°). The improvement in localization was most marked between 0° and 10°, and 10° and 20°. The improvement between 20° and 30° was not so noticeable.
d) The test signal generated by the Level-Difference-only microphone configuration, produced notably poor overall localization compared with the Time Difference and Hybrid test signals. There was still a progression in the quality of virtual localization with the increase in the diagonal loudspeaker position angle towards the 30° limit of the tests, but the final localization quality was definitely inferior to all the signals containing a Time Difference component.

7. ANALYSIS OF THE RESULTS OF THE 2ND LAYER LOCALIZATION CHARACTERISTICS

The second layer was made up of four figure of eight microphones pointing at 90° to the horizontal plane and spaced at 52cm between each capsule, as shown in Figure 8. With these Schoeps CCM 8 Figure of Eight microphones the directivity patterns are actually pointing upwards at 90° to the body of the microphone as shown in Figure 1.

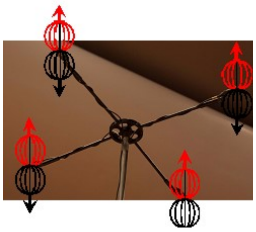

FIGURE 1 – 2ND LAYER FIGURE OF EIGHT MICROPHONES

According to the SRA diagrams [4] and the spacing used between the microphones (52cm) the microphone pair should produce a Stereophonic Recording Angle (SRA) of +/-50°. This was confirmed in the listening tests. With the reference plane of the microphone pair placed in the horizontal plane, the SRA was maintained up to an angle of about 50° both above and below this horizontal reference plane, as would be expected.

8. DESCRIPTION AND ANALYSIS OF THE ACOUSTIC LAYER SWITCH MECHANISM

This concerns the interaction between the two layers of the 12 channel array, i.e. the sound catchment of the second layer of vertical spaced figure of eight microphones with respect to the 1^{st} layer of microphones of the M.A.G.I.C. array.

Although this 12 channel 3D Multiformat array (as shown in Figure 2) was first designed to avoid interaction between the two layers, it was evident from the Göteborg experimental recordings that some interaction was taking place. If no interaction was present then changing the distance between the 1^{st} and 2^{nd} layer microphones would not change the sound reproduction characteristics. This proved to be inexact. When the distance between the two layers was reduced to about 10cm, the height information collapsed completely. Another indication was that when the height layer microphones were changed to supercardioids and were oriented at 45° in the vertical plane, so that they would to pick up some of the direct sound information, the whole of the lower layer of reproduction was transported towards the height loudspeakers.

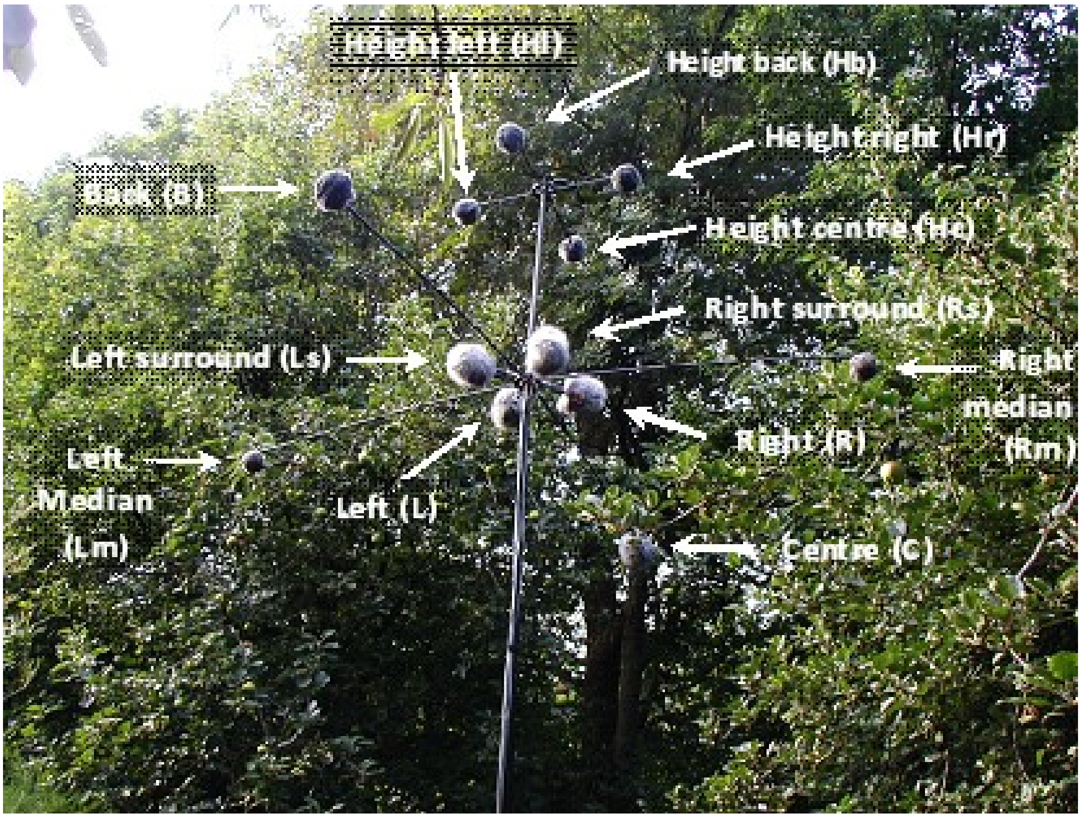

FIGURE 2 – THE COMBINED 1^{ST} AND 2^{ND} LAYERS - THE FULL TWELVE CHANNEL ARRAY

The use of vertical figure of eights in the 2nd layer at a distance of 1m from the lower layer was therefore considered necessary to reduce interaction but this distance parameter needed further investigation. For the initial testing only one microphone was taken from each layer of the array. These two microphones form a spaced pair configuration with a cardioid and a figure of eight microphone orientated so that there was 90° between the axes of directivity, and a distance of 100cm between the capsules. This is a most unusual combination and so needs careful analysis. Figure 3 shows the plan view of this microphone pair, together with the Time Axis, Level Axis and perceived Overall Axis.

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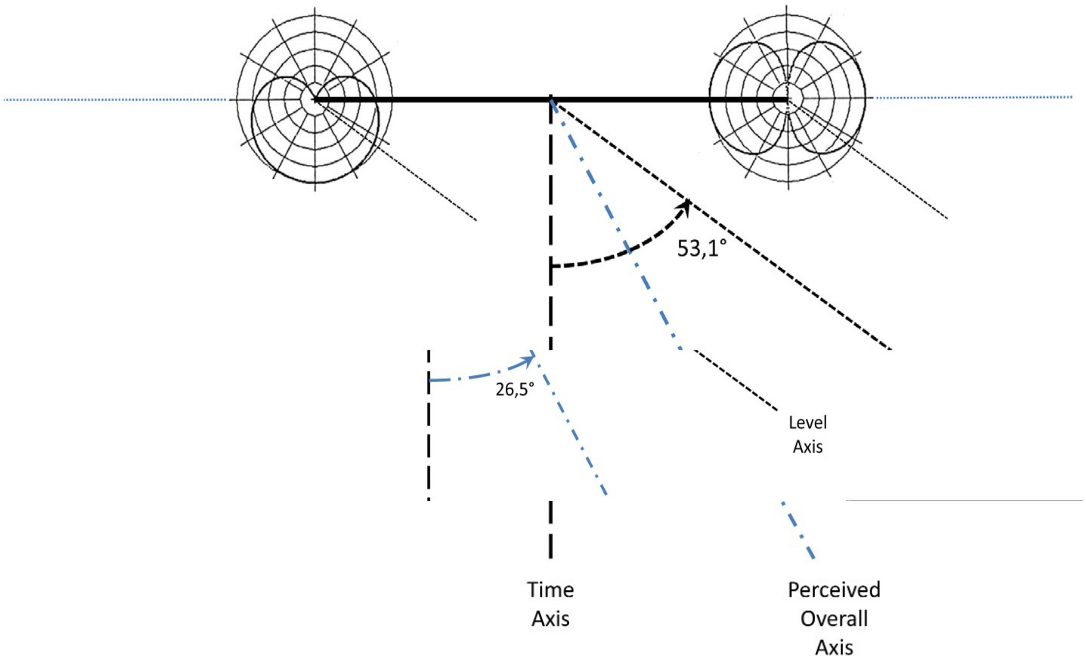

FIGURE 3 – AXES

FIGURE 3 AXES OF THE VERTICAL LAYER SWITCH

In Figure 3 we use the Time Difference axis as the reference axis of the system i.e. the axis that is perpendicular to the line between the microphone capsules. The Level Difference axis occurs when the Level Difference between the microphones is 0db. This in fact occurs at 53.1° (anticlockwise) when the level response of each microphone is the same.

The general axis of the system is perceived to be at about 26.5°, about half way between the Time Difference and Level Difference axes. In the standard stereophonic loudspeaker configuration this general system axis should be perceived at about the center position between the two loudspeakers. This should also be the case if listening tests are carried out using a diagonal pair of loudspeakers.

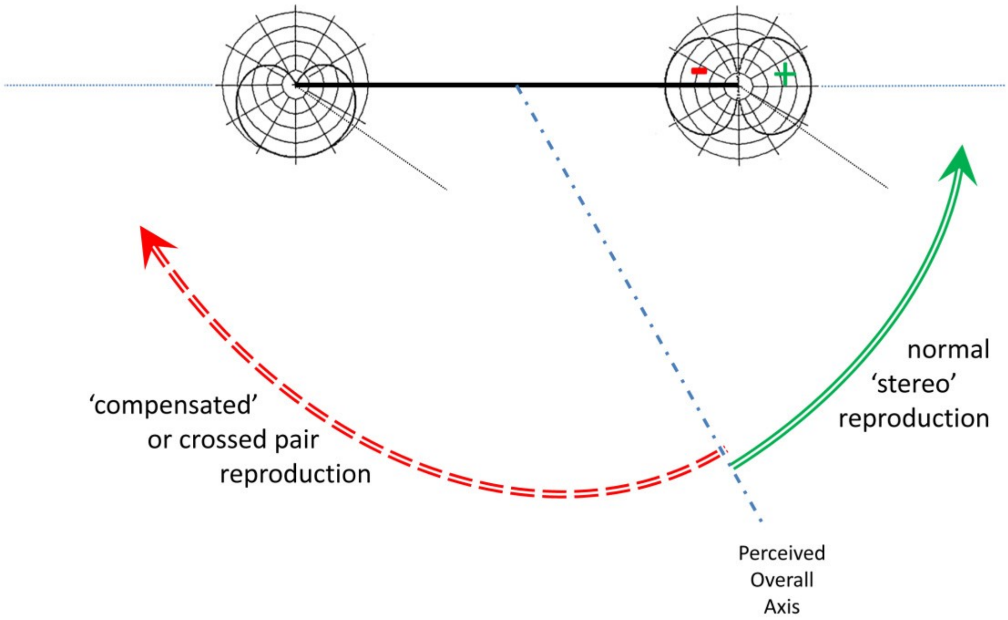

FIGURE 4 – SOUND SOURCE LOCALISATION
ON EITHER SIDE OF THE PERCIEVED GENERAL AXIS

The displacement of the sound source clockwise and anticlockwise, as shown in Figure 4, will produce two very different reproduction characteristics. To the anticlockwise side of the general axis (shown in green in the Figure 4), we will get normal 'stereophonic reproduction with a clear virtual image moving to the right of center between the loudspeakers. Movement of the sound source in the clockwise direction (shown in red in Figure 4) will produce no clear virtual localization. The Time Difference and Level difference functions are in opposition AND there is polarity inversion between the cardioid microphone and the back lobe of the figure of eight microphone (most people unfortunately use the misnomer of calling this 'phase' inversion).

The effect has to be heard, to really be understood! But the effect on perception in reproduction in this test, is that most of the sound seems to be coming from the left hand loudspeaker. Again the only way to clearly understand this characteristic is to do the experiment oneself.

If we now rotate the pair so that the two microphones are one above the other; the figure of eight being uppermost, then then the microphones are in the same configuration as the 12 channel 3D Multiformat Array, with the figure of eights pointing vertically above the lower 1st layer. We see therefore that from an elevation angle higher than 26.5° the reproduction is normal virual sound source reproduction, whilst below this elevation angle reproduction is concentrated on the 1st or lower layer of loudspeakers. This is why I have called this phenomena 'the Acoustic Layer Switch Mechanism' – at around 26.5° we switch from the 1st layer reproduction to a virtual sound source reproduction in the 2nd layer, as we progress to the higher positions of the sound source – we gradually switch to the reproduction characteristics of the four figure of eights in a 52cm square as described in Section 7.

9. THE BASIC ISOSCELES TRIANGLE STRUCTURE

If we configure an isosceles triangle structure for microphones and loudspeakers then the 1st layer and 2nd layer microphones will be reproduced on the diagonals between the loudspeakers. The perceived 'general axis' of each microphone/loudspeaker pair will be situated about halfway along the diagonals for each of the isosceles triangle segments.

With a 12 channel Array system, we will consider two possible orientations for the height microphones. The 52cm square of vertically orientated figure of eights is mounted so that

- The microphones support arms are pointing towards 0°, 90° 180° and 270°, (as shown in Figure 5). This means that the loudspeaker positions have to be configured similarly. All the above listening test of music and natural ambience recordings were done using this configuration.
- The microphone arms are pointing at 45°, 135°, 225° and 315° (this configuration will be compatible with the 12 channel Auro 3D configuration).

In the first case, the relative positions of the main MAGIC layer and the 2nd or top layer is such that each 2nd layer microphone forms an isosceles triangle with two of the microphones in the Quad Square. We will call the 2nd layer microphones Hc (Height centre at 0°), Hl (Height left at 270°), Hr (Height right at 90°) & Hb (Height back at 180°). As can been seen in Figure 5, the primary set of isosceles triangles are formed by:

- L, R and Hc in the front (in white)
- Ls, L and HL on the left hand side (in red)
- R, Rs and HR on the right hand side(in green)
- Rs, Ls and HB at the back (in black)

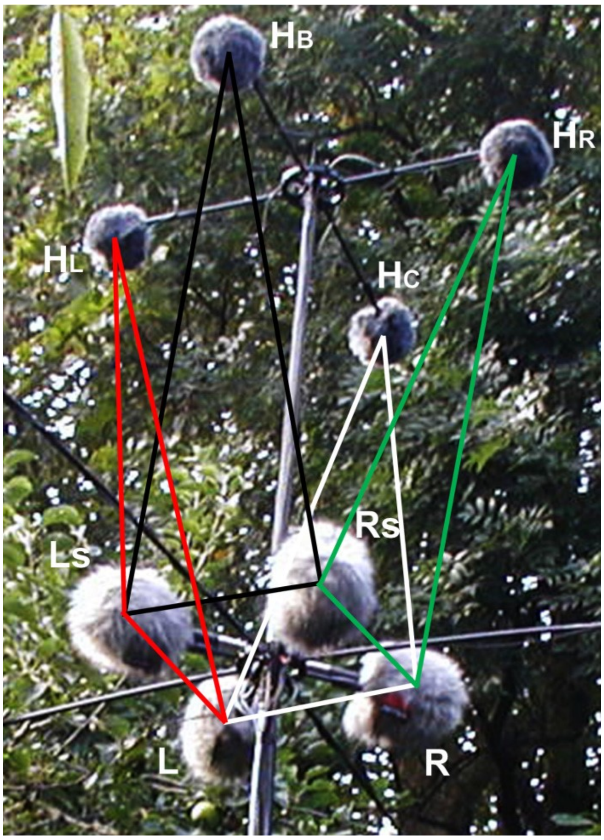

FIGURE 5 – THE PRIMARY ISOSCELES TRIANGLE IN THE 12 CHANNEL MICROPHONE ARRAYAXES OF THE VERTICAL LAYER SWITCH

Figure 6 shows the Primary Isosceles Triangle Structure in the temporary listening room installed at the Applied Acoustics Department of Göteborg University.

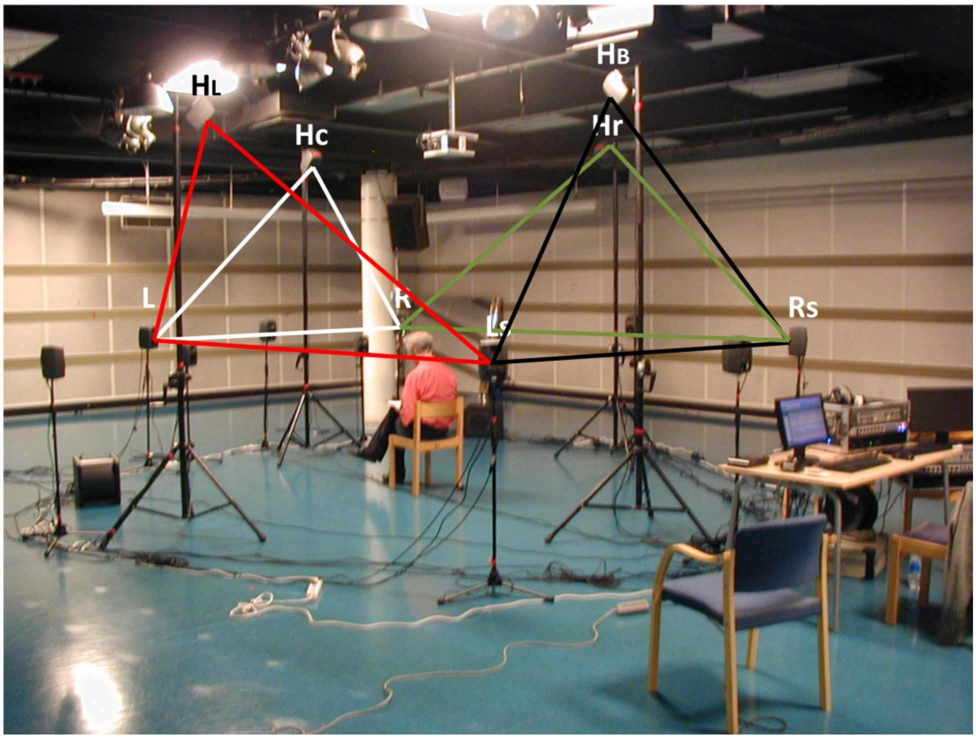

FIGURE 6 – THE ISOSCELES TRIANGLE STRUCTURE
IN THE TEMPORARY LISTENING ROOM AT THE UNIVERSITY OF GÖTEBORG

It could be said that, in the full 12 channel microphone array configuration, the four satellite MAGIC array microphones and corresponding loudspeakers are redundant, as in fact a perfectly satisfactory 3D sound image is obtained by using only eight microphones – the central Quad Square part of the MAGIC array and the Figure of Eight Cross of the 2nd Layer. But if only eight microphone channels are recorded then this would mean that the master recording would not contain information that was compatible with the 5 channel multichannel format or the 7 channel blu-ray format. So in practice all 12 channels must be recorded for full compatibility. But if a strict minimalist approach is considered desirable then these loudspeakers and microphones can be considered as optional

However there was some slight improvement in the overall quality of reproduction with all 12 channels.

In the second case, the listening configuration, which is shown in Figure 7, was setup in Galaxy Studios in Mol, Belgium. Here the primary isosceles triangle loudspeaker structure was formed by:

- L**M**, H**L** and C on the left front side(in red)
- C, H**R**,and Rm on the right front side (in green)
- R**M**, H**RS** and B on the right back side(in blue)
- L**M**, H**LS** and B on the left back side(in yellow)

This structure is compatible with the 12 channel Auro 3D configuration when the height part of th e microphone array is as specified in this second case (45°, 135°, 225° and 315°). The 12 channel Auro 3D system coding was also considered as a possible recording media for this type of recording.

9.1.

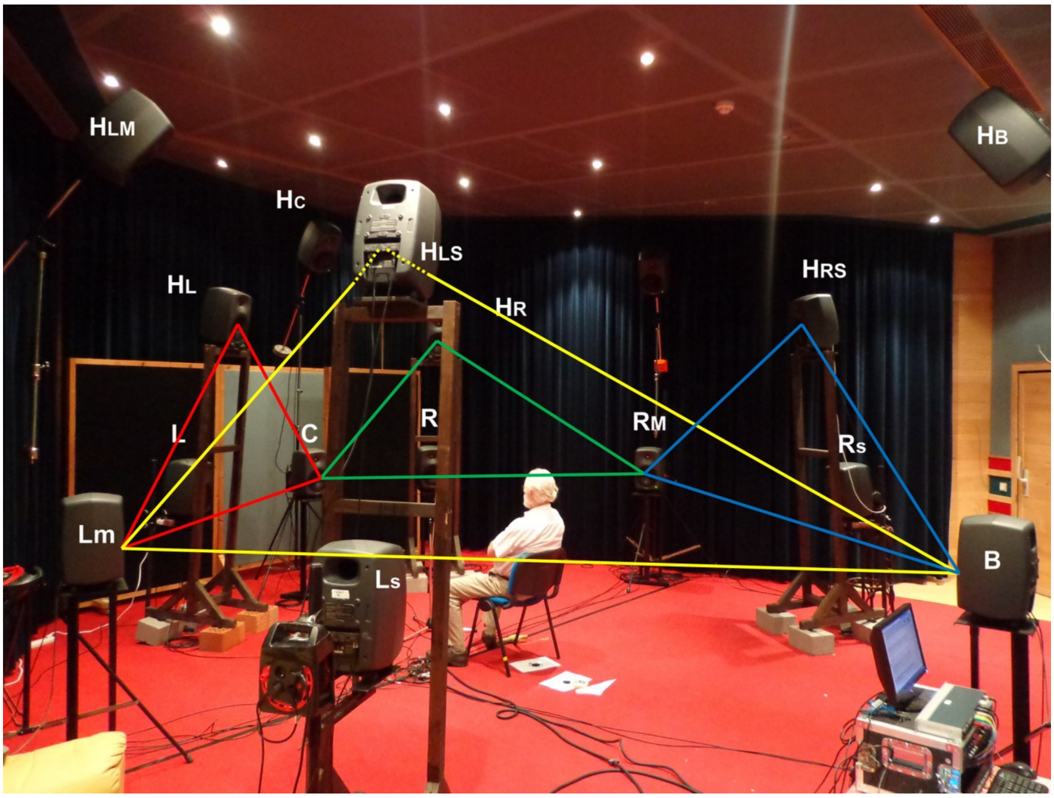

FIGURE 7 – THE ISOSCELES TRIANGLE STRUCTURE
IN THE TEMPORARY LISTENING ROOM AT GALAXY STUDIOS
(COMPATIBLE WITH 12 CHANNEL AUDRO 3D)

We can see from these two examples (at the Göteborg University and at Galaxy Studios) that the isosceles triangle microphone array and loudspeaker structure can be applied to a certain number of array configurations. It is hoped to be able to carry out a further program of research and development concerning this approach to 3D microphone array recording and reproduction.

10. THE GOART PROJECT - THE ORGAN AS MEMORY BANK.

This project was in fact the trigger to this program of research and development into 3D array recording. The Organ as a Memory Bank is itself a research project at the Göteborg Organ Art Center (GOArt), University of Göteborg, financed by the Swedish Research Council, and carried out in collaboration with the Division of Applied Acoustics, Chalmers University of Technology, Göteborg.

The historical organs of Sweden and Europe form a cultural landscape of great national and international significance and constitute an important map of both tangible and intangible cultural heritage. Questions of conservation of this heritage has been addressed in Sweden because of the change in relationship between the Swedish State and the Swedish Church. The organ, as well as all other inventories, were specifically mentioned when the Swedish legislation regarding Cultural Heritage was updated in 1999.

The organ can be seen as a collective memory bank of multiple kinds of handcraft, traditions of instrument building and specific developments within music performance. A typical organ is made up of many thousands of parts and is often contained in a case that can be as large as a small house. Performing a thorough technical documentation is part of the work of safeguarding the cultural heritage built into the organ and its case. Thorough documentation of the organ and its case can be a daunting task. A technical documentation only partly provides information for a better understanding of the intangible heritage that each of these objects encompasses. Photos and recordings of pipe and register sounds as well as music performances are a part of the documentation that must be preserved.

Since 1995 when the Göteborg Organ Art Center was established, documentation of the physical properties of the organ has been an important part of its research. To complement this documentation, GOArt has also developed a research model in which the building of a copy of an organ as close as possible to a well-preserved original helps verify the technical documentation, and rediscover the tacit knowledge that these objects contain, which normally is not accessible through measurement and observation alone. Through several documentation and research projects, encouraging collaboration between instrument builders, engineers, conservators and antiquarians, GOArt uses its "Organ Documentation Manual" to structure the information collected in the database.

Documentation of the sound of an organ and its habitat before and after restoration or other work is needed and has not been systematically and comprehensively done earlier. A sound recording, based on current technology developed for the commercial market, does not suffice as a technical documentation. In spite of this being current practice, and as such, well established and functional for its own needs, any commercial recording will be strongly affected by artistic judgments made by the recording engineer. It is therefore important for documentation purposes to develop a durable scientific and psycho-acoustically relevant sound documentation methodology. It is necessary to develop an optimal recording method and define the necessary equipment, analysis and evaluation methods and also to develop and define the optimal presentation methods for the sound documentation.

Organ pipes are designed and voiced with consideration for the acoustic properties of the room in which the organ is situated (from the acoustic point of view the room is certainly a "part of" the instrument). It was considered necessary to look for an optimal "neutral" recording and playback technique to archive realistic reproduction of the organ and its surrounding acoustics, and be able use this recording as a reproduction tool for comparison with any future modifications. Optimal techniques must be developed that will allow the playback formats to remain available to researchers and the general public now and as far as possible into the future. In contrast to the printed word, the sound documentation may need to be "reformatted" at various times with respect to advances in audio technology, in order to remain accessible.

The 3D/Multiformat Microphone Array Design, proposed by Michael Williams and described in AES Convention papers 7057[1] and 8601[2], was considered as a possible recording system. A trial period was arranged in August 2012 by the Göteborg Organ Center and the Department of Applied Acoustics of the University of Göteborg represented by Professor Mendel Kleiner. Four different venues in Göteborg were proposed for the recordings - the Ôrgryte Nya Kyrka (in Figure 1)(Organist – Joel Speerstra). the Organ Hall in the Academy of Music and Drama of Göteborg (Organist – Svetla Tsvetkova), the Mariakyrkan (Organist – Per Högberg) and the Vasa Kyrkan (Organist – Per Högberg).

11. THE GOART LISTENING TESTS.

First of all it must be said that the recordings in the four churches selected, were done WITHOUT the presence of the GOArt listening panel. They therefore had no knowledge of the techniques used to create the recordings. They were however asked to attend live listening session in the churches afterwards, listening to the same extracts as had been recorded. No recording equipment was present for these later sessions. They were asked to fill out a questionnaire concerning their appreciation of the sound of the organ and the church environment.

The listening panel was then invited to attend, individually, listening tests at the Applied Acoustics Dept. of Göteborg University where they were able to hear the original recordings. They were again asked to fill out a questionnaire concerning their perception of the sound of the organ and its acoustic environment.

In each church, three specific positions of the microphone array were recorded, with small variations in position according to the organ structure and acoustics of each church. There was a close correspondence between the live listening impressions and the 3D reproduction listening tests. One person in particular on the listening panel (Munetaka Yokota - Organ Builder and researcher with the Götberg Organ Art Center) was able to locate the three positions of the recording array to within 50cm, without any previous knowledge of the actual positions used. This was indeed a remarkable performance, and confirmed that this person had exceptional 'golden ears'! His appreciation of the sound image was based also on an exceptional knowledge of the timbre of the organ (of the Ôrgate Nya Kirka), coupled with a considerable experience of the acoustics of the church – he was in fact responsible for the manufacture, tuning and voicing of the pipes in the organ!

However this remarkable identification of the recording positions would not have been possible if the microphone array recording and reproduction system itself did not produce an exceptionally realistic reproduction of the organ and its surrounding acoustic environment.

The reconstruction of the North German Baroque Organ for the Orgryte Nya kyrka is described in a book entitled 'Tracing the Organ Master's Secrets' published by GOArt Publications, Göteborg University – ISBN 140468825.

12. LISTENING TESTS USING MUSIC AND NATURAL AMBIENCE RECORDINGS.

Even though listening sessions were carried out later at Galaxy, ITEMM and the INA, using the music and natural ambience recordings, no strictly formal listening tests were organized. But the general impression from the 70 or 80 people who listened to these recordings was generally of realistic and robust 3D sound reproduction.

13. MICROPHONE SUPPORT SYSTEM

As usual with any of these muti-microphone array recordings, one of the major difficulties to be overcome is the mechanical microphone support system. In the Göteborg project, the 'Williams 12 channel Star' support system was used. Although the system worked correctly, the time for installation was considered too long (a couple of hours). As the visual impact of the microphone support system was not a major consideration, a new system was put into development soon after, which was designed to reduce installation time to a matter of minutes. This new system was presented at the 2012 Tonmeistertagung in Cologne (VDT/tmt27) [5] (as shown in Figure 8), together with an interim report on this research project. The array system was equipped with 4 x Schoeps CCM 21 for the 1st layer inner hub, 4 x Schoeps CCM 4 for the 1st layer satellite microphones and 4 x Schoeps CCM 8 for the 2nd height layer.

FIGURE 8 – THE 12 CHANNEL 3D MULTIFORMAT MICROPHONE ARRAY SUPPORT SYSTEM CALLED THE 'WILLIAMS 12 CHANNEL UMBRELLA'
(PHOTO BY KIND PERMISSION OF JORG WUTTKE TAKEN AT THE 2012 TONMEISTERTAGUNG IN KÖLN

14. ACKNOWLEDGEMENTS

I would like to thank the many people who have helped in this project up to now. First of all Mendel Kleiner, Professor of Applied Acoustics at the Division of Applied Acoustics, Chalmers University of Technology, Göteborg, who really gave momentum to my work on this project. Erkin Asutay, PhD student with the Applied Acoustics lab, in Göteborg for his help in the tesing process, and the members of the GOART (Göteborg Organ Art Center) who participated in the listening panel for the GOArt Organ Project – 'The Organ as Memory Bank'.

I would also like to thank Hugo Romano and Santi Barguño from Neu Records (www.neurecords.com) in Barcelona for permission to record the session of contemporary music by Ramon Humet, performed by the London Sinfonietta in the Watford Colosseum in London in January 2012. Neu Records will be publishing their own recording of this session.

Thanks are also due to Wilfried van Baelen, CEO of Auro Technologies and Galaxy Studios, for giving access to some wonderful studio and listening room facilities at Galaxy Studios and participating also in the listening tests. Thanks also to Milber Ferreira, who was a technician at Galaxy studios at the time, for his help in setting up the tests and for participating fully in the spirit of the tests themselves.

'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 at the ITEMM studying for the title of 'Régisseur son du spectacle vivant ou de la production multimédia' for their participation in the clarinette trio recordings and listening tests, and of course to the musicians (Elouan Trichard, William Ross & Adrien Stauch) from the Conservatoire à rayonnement départemental du Mans (CRD du Mans)..

And last but not least my thanks to Bergame Periaux and Vincent Magnier. Bergame Periaux is 'responsable de la filère de formation au son multicanal and INA expert' at the 'Institut national de l'audiovisuel (INA)' in Bry sur Marne, near Paris, and Vincent Magnier is 'Chef operateur du son' (freelance sound recording engineer) , and 'formateur' at the INA.

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