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Recording and post-production of Dietrich Buxtehude's baroque cantatas in stereo and Dolby Atmos using experimental 3D microphone array.

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ABSTRACT

3D recordings seem to be an attractive solution when trying to achieve the immersion effect. Recently, Dolby Atmos is an increasingly popular format for distributing three-dimensional music recordings. Although currently the main format for producing music recordings is still stereophony. How to optimally extend traditional microphone techniques when recording classical music to obtain both stereo recordings and three-dimensional formats (e.g. Dolby Atmos) in the post-production process? The author is trying to answer this question using the example of a recording of Dietrich Buxtehude's work "Membra Jesu Nostri", BuxWV 75. The cycle of seven cantatas composed in 1680 is one of the most important and most popular compositions of the early Baroque era. The author will present his concept of a set of microphones for 3D recordings with detailed setup. Finally, the results of listening tests based on a comparison of the stereo version with two different immersive mixes will be presented.

1 Introduction

Technological evolution is ongoing. The most general goal of which is to adapt the way recordings are made to the sublime and very complex possibilities of human perception and to expand the possibilities of artistic expression of creators [10]. A term that appears more and more often in the context of the reception of art, including music recordings, is immersion [6, 8]. Immersion combines physical, technical and acoustic parameters with sound perception and music psychology. 3D recordings seem to be an attractive solution when trying to achieve the immersion effect [9]. Recently, Dolby Atmos is an increasingly popular format for distributing three-dimensional music recordings [13]. Although currently the main format for producing music recordings is still stereophony.

Basic stereophonic techniques, i.e. AB, XY, ORTF or M/S, enable sound engineers to satisfactorily realize their artistic intentions on this technological basis [1, 2]. In the case of three-dimensional sound reproduction systems, the situation is much more complicated. There are at least 250 microphone systems currently described that enable the creation of such a recording, including: PCMA-3D, OCT-3D, 2L-Cube, Decca Cuboid or Hamasaki Square [3, 4, 5, 7, 11, 12, 14, 18].

How to optimally extend traditional microphone techniques when recording classical music to obtain both stereo recordings and three-dimensional formats (e.g. Dolby Atmos) in the post-production process?

2 3D recording concept

The author used his concept of an optimized set of microphones for 3D recordings.

Features of the optimized experimental 3D microphone array are:

- useful and comprehensive intensity-time information
- easy installation of microphones
- not too many additional channels (single microphones)
- scalability to various formats
- use of 3D microphone array elements also for stereo recording
- high signal quality from microphone capsules (compared to some ambisonic microphones).

The proposed experimental microphoneization method was based on the Twins Cube technique by Gregor Zieliński [14] - a sound engineer specializing in immersive recordings of classical music. There were three main reasons for choosing the Twins Cube technique. The first one is related to the fact that this microphoneization method is based on the stereophonic AB technique, most often used in contemporary recordings of classical music. This allows the use of microphone signals to prepare both stereophonic and immersive formats, which speaks in favor of the universality of such a solution. The second reason is the simplicity of Gregor Zieliński's microphone system, its ease of assembly and the possibility of constructing it using frequently used and available devices. The third reason, also significant, is the very good opinions and reviews collected over the years of Gregor Zieliński's recording work from musicians, music lovers and music critics.

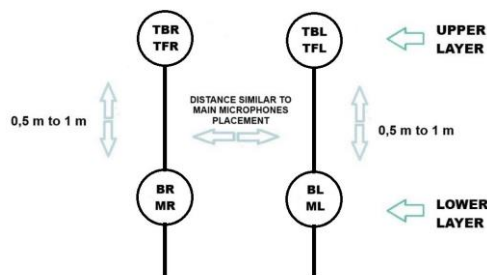


Figure 1. Original 3D microphoneization method – frontal view.

In Gregor Zieliński's original concept of the Twins Cube system, MKH 800 Twin microphones from Sennheiser were used [15]. These are devices that consist of two condenser directional capsules placed opposite. Such a structure allows the adjustment of the microphone's resultant directivity

by appropriately summing the characteristics. Since the capsules have separate outputs, there is also the possibility of separate panning of signals, and this feature is key when directing them to different channels of the immersive system. In the experimental method of microphoneization, each of the MKH 800 Twin was replaced by two condenser microphones, selected depending on the needs and preferences. So the four Sennheiser devices from the Twins Cube system were replaced by eight individual microphones (Figure 1 and 2) in the following configuration: TBR – top/back/right, TBL – top/back/left, TFR – top/front/right, TFL – top/front/left, BR – back/right, BL – back/left, MR – main/right and ML – main/left. The selection of the microphone type and its directional characteristic is based on exactly the same assumptions as in the case of sound engineering for stereo recordings. The recording engineer takes into account the quality of the signal from the given microphone, the matching of the directional characteristic to the acoustics of the room in which the recording is made, the type and size of the band and the expected spatial values.

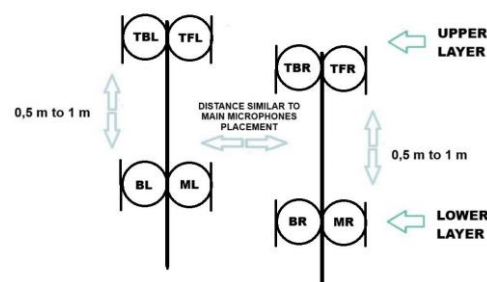


Figure 2. Original 3D microphoneization method – side/back view.

Using the above-described microphone method, 10 test recordings have been made since November 2023 to check how the recorded signals work to create 3D space in Dolby Atmos technology. The recordings were made in rooms with different acoustics (from cinemas and recording studios through concert halls to sacral interiors) and for various ensembles (from duets through choirs to orchestras and vocal-instrumental groups). The vertical position of the microphones, the distance between the capsules on the left and right, and the selection of the directional characteristics of the system components were tested.

3 Recording setup

The test recording was the first cantata “Ad pedes” from the collection “Membra Jesu Nostri” BuxWV 75 by Dietrich Buxtehude performed by the Arte Dei Suonatori ensemble, accompanied by soloists: Marzena Michałowska (soprano), Marta Krysiak (soprano), Piotr Olech (countertenor), Karol Kozłowski (tenor) and Maciej Straburzyński (bass). The choral parts were performed by the choir of the University of Zielona Góra Cantus humanus, and led by conductor Bartłomiej Stankowiak. The length of the recording is 8 minutes and 24 seconds. It was made in early October 2024 in the church in Lipno near Zielona Góra.

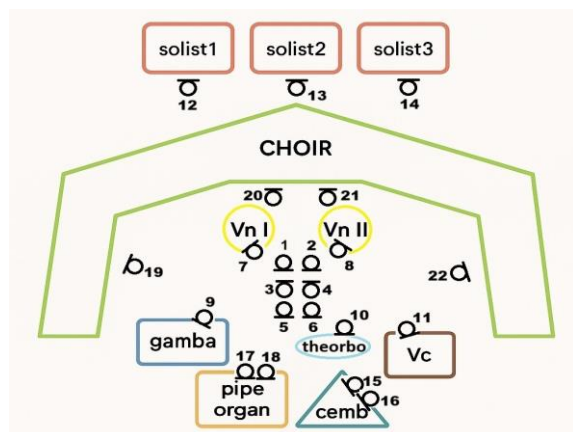


Figure 3. Arrangement of musicians and microphones during the recording of D. Buxtehude's cantatas in the church in Lipno.

For the recording of D. Buxtehude's cantatas, in addition to the standard set of microphones used for stereo recordings, a reduced version of the experimental 3D technique was used (Figure 3, Table 1). The four top microphones: TBR – top/back/right, TBL – top/back/left, TFR – top/front/right, TFL – top/front/left, were replaced by two TL – top/left and TR – top/right. This solution turned out to be very useful and sonically satisfactory during earlier recordings and test remixes. An important element of this version of the 3D microphone system is the use of omnidirectional capsules as the top-level microphones. The main microphone array in this case consists of 6 elements. In addition to the two upper layer microphones, it is composed of 4 lower layer microphones: BR – back/right, BL – back/left, MR – main/right and ML – main/left. The width between the main microphones was 0.6 meters and the distance between layers was 1 meter.

Mic no	Mic symbol	Mic function	Microphone type
1	TL	top/left	Line Audio OM1
2	TR	top/right	Line Audio OM1
3	BL	back/left	Line Audio CM3
4	BR	back/right	Line Audio CM3
5	ML	main/left	Schoeps MK2S
6	MR	main/right	Schoeps MK2S
7	VI I	violin I	sE Electronic 4400
8	VI II	violin II	sE Electronic 4400
9	gamba	viola da gamba	Rode NT2A
10	theorbo	theorbo	Schoeps MK21
11	Vc	cello	Schoeps MK21
12	solist I	solist I	Rode NT5
13	solist II	solist II	Rode NT5
14	solist III	solist III	Rode NT5
15	cembalo	cembalo left	Rode NT5
16	cembalo	cembalo right	Rode NT5
17	pipe organ	pipe organ left	Line Audio CM3
18	pipe organ	pipe organ right	Line Audio CM3
19	choir	choir left	Line Audio CM3
20	choir	choir middle left	Line Audio CM3
21	choir	choir middle right	Line Audio CM3
22	choir	choir right	Line Audio CM3

Table 1. List of microphones used in the recording of D. Buxtehude's cantatas.

4 Listening tests

The first listening tests were carried out in March 2025. The listening experiment was conducted based on the guidelines of the European Broadcasting Union (EBU) [16]. The listening room was a control room with a calibrated Neumann loudspeaker system in a 7.2.4 configuration. The group of experts consisted of first- and second-year students of sound engineering at the Faculty of Composition, Music Theory and Sound Engineering of the Feliks Nowowiejski Academy of Music in

Bydgoszcz. They had already experienced listening to immersive recordings in the Dolby Atmos format in a given room. They were also familiarized in detail with the parameters that were assessed during the tests. Before starting the experiment, the volume of all three samples was equalized to an average listening level of 70 dBA. The experts had at their disposal a 7-point rating scale from 1, meaning that the parameter was in their opinion very bad and unfavorable, to 7, meaning the highest possible preference and the best effect.

The experts listened to three versions of the recording in a row:

1. **Stereo** - stereo version.
2. **Atmos1** - Dolby Atmos version, in which the spatial mix corresponded to the stereo mix in terms of instruments and voices locations. The sound sources were placed in front of the sound image, creating a traditional arrangement similar to concert performances. The listener was placed in front of the entire band. The signal to the side, rear and top speakers came almost exclusively from the additional 4 microphones of the immersive system.
3. **Atmos2** - Dolby Atmos version, in which the listener was located in the middle of the band. The spot microphones of the individual sound sources were panned in three-dimensional space in accordance with their actual positioning relative to the main microphone array during the recording session (Figure 3).

	stereo	Atmos1	Atmos2
1. Front image quality	5,67	5,68	6,11
2. Side and rear sound quality	x	6,22	5,56
3. Spatial impression	4,11	6,22	5,61
4. Transparency	5,22	6,00	6,17
5. Balance	4,70	5,22	5,39
6. Sound colour	5,33	6,06	5,78
7. Freedom from noise and distortions	6,11	6,56	6,22
8. Main impression	5,04	6,10	5,97

Table 2. Results of listening tests – average values.

The table above presents the average results obtained from 9 experts who took part in the listening experiment (Table 2). An interesting conclusion from the analysis of the collected results is the value of the general impression parameter for individual samples. Both recordings in the Dolby Atmos format received a higher score (by about 1 point) than the recording in the stereo format. All experts preferred the immersive versions of the recording of Dietrich Buxtehude's work. The differences between the two versions of the recording in the Dolby Atmos format are insignificant, with a general indication of the Atmos1 version, i.e. the one in which all the instruments and voices are panned in front of the listener. Interesting partial results when comparing individual parameters were outlined in the parameters of the quality of the sound image from the front and the transparency of the recording. In these two parameters, the experts preferred the Atmos2 sample. The reason for such results may be the panning of the spot microphones of instruments placed behind the listener (harpsichord, positive organ, cello, theorbo) in a different place than instruments and voices placed in front of the listener (two violins, choir, soloists). This reduces the amount of uncontrolled crosstalk from the spot microphones overlapping in the same place of the sound image, which results in an improvement in the quality of the sound image from the front and an increase in the perceptibility of details of individual sound sources (transparency parameter). The Atmos1 sample is preferred over Atmos2 in the spatial impression parameter (6.22 to 5.61). This may be due to the fact that in this version of the immersive mix, in which all sound sources are placed in front of the listener, experts can hear the quality and presence of the reverberation more clearly. It is not psychoacoustically masked by the presence of instruments in the side and rear speakers. Similar reasons supports the experts' preference for the Atmos1 sample over Atmos2 for the side and rear sound quality parameter (6.22 to 5.56).

5 Conclusions

The experiments conducted so far show great potential in the use of 3D sound and the Dolby Atmos format in phonography. From the perspective of a recording engineer, the possibility of creating phonograms in three axes of space is exciting. For

the sound director, new possibilities appear which could be described as topophonic interpretation of the phonogram. There are still many questions about the validity of aesthetic choices and also about how to listen to immersive recordings. The vast majority of listeners use headphones for this, so they listen to the binaural version of the multichannel recording. Researches shows big differences, for example, in the localization of sound sources for different binaural renderers [17]. So how can we predict and design the spatial structure of a recording if there are so many uncontrollable variables on the recipient's side? Maybe, in connection with the above statistics, it is worth expanding the listening experiment to include binaural recordings.

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