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Study of Preference for Surround Microphone Techniques Used in the Recording of Choir and Instrumental Ensemble

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The aim of this paper is to describe the process of choosing the best surround microphone technique for recording of choir with an instrumental ensemble. First, examples of multichannel microphone techniques including those used in the recording are described. Then, the assumptions and details of music recording in Radio Gdansk Studio are provided as well as the process of mixing of the multichannel recording. The extensive subjective tests were performed employing a group of sound engineers and students in order to find the most preferable recording techniques. Because the final recording is based on the mix of "direct/ambient" and "direct-sound all-around" approaches, a subjective quality evaluation was conducted and on this basis the best rated multichannel techniques were chosen. The results show that listeners might consider different factors when choosing the best rated multichannel techniques in separate tasks, as different systems were chosen in the two tests.

Keywords: surround microphone techniques, musical recording, direct/ambient, direct-sound all-around.

1. Introduction

The main purpose of surround systems is to produce a sound field that envelopes the listener in the way that was not possible to be achieved in traditional two-channel systems. Such systems were developed by adding additional channels (speakers) to existing two-channel solution in order to eliminate its disadvantages such as narrow sweet spot. Although there is no limitation to the number of channels of stereo surround systems, one of the most popular solutions is a six-channel system denoted as 3/2 or 5.1 in the ITU-R BS.775-1 recommendation (ITU, 1992). The above mentioned standard was a "compromise between the need for optimum spatial enhancement of reproduction and the need for an approach that was practicable and compatible with conventional two-channel reproduction"

(AES, 2001). In addition, the multichannel recording can give better flexibility and spatial quality in comparison to stereo recording (Rumsey, 2002).

One of the most important aspects which should be considered in preparing a multichannel recording is the decision as to which perspective to present. The first approach – direct/ambient – attempts to recreate the impression of taking part in an event. The three front channels are supposed to reproduce the sound field of the sound source, while surround channels produce ambient sounds (ambience, reverberations, enveloping ambience, applause, etc.) that are unachievable in traditional 2.0 systems (Holman, 2007). This approach can be specified as a classic method and does not oblige the sound engineer to use the LFE channel. Its main aim is to create the atmosphere of sitting in the audience of a concert room in front of the performing ensemble (Holman, 2000). Even though, it should be remembered that the ratio of direct to ambient reflected signals is very different for a musician in the orchestra, the conductor in front of the orchestra or a member of the audience behind the conductor in the concert hall (Linkwitz, 2010). Thus it is often difficult to say whether it is the musician's perspective, the conductor's or the audience's. The second perspective, which may be an artificial perspective that serves a particular purpose, provides the listener with a new kind of experience that cannot be achieved during a concert. It involves placing the person inside a band. In this approach any of the speakers can become a source of both direct and reflected sound. This is called "direct-sound all-around" and because the sources are placed around the listener it is a "middle of the band" perspective (Holman, 2007). In this case, it is recommended to use the LFE channel, for example to emphasize the sound of bass instruments reproduced by the full-bandwidth speakers. By using this perspective, a wider sound stage than in the traditional two-channel stereophonic systems is achieved. As a result, the obtained sound image may not be fully realistic but whether it is or not depends mostly on the genre of music (Owsinski, 1999).

Yet, another approach to setting a perspective is conversion from two channel stereo recording into multi-channel format 5.1 by means of the HRTF filtering (Hen *et al.*, 2008). Also, a very interesting approach during the mixing of the recording was used by Mickiewicz and Jelen (2008). The direct send channels serve exclusively to form the central and low frequency effect channel (LFE). This configuration was applied to make the final mixdown of a multichannel recording of the choir concert with the use of the Optimized Cardioid Triangle (OCT) microphone array. However, in this paper only the two first approaches were utilized and compared.

Even though this set of considerations given above is very important from the listener's point of view, one should be aware that there are several additional or rather key issues that should examined by the sound engineer. These issues were presented by Woszczyk and Bregman (2005) in their article entitled: "Creating Mixtures: The Application of Auditory Scene Analysis (ASA) to Audio Recording". The article focuses on the application of principles of auditory scene analysis (ASA) to the art of recording. Moreover, the authors of this paper show that auditory and visual perception are not two independent processes functioning in isolation. Both modalities cooperate towards improving human efficiency and ability to track events in a surrounding environment. This is obvious in case when audio-visual information is simultaneously provided to the audience, however audio-visual integration also happens in the case when the image is not present because of an individual experience and in accord with expectations.

This article presents assumptions and details of music recording of a gospel choir and the accompanying band, which took place in the Radio Gdansk Studio. The music recording was prepared by A. Sitek's for his M.Sc. thesis (Sitek, 2010). The band and the choir were recorded separately during a two-day recording session. The "direct-sound all-around" approach was chosen for the recording of the band, and for this reason the optimum separation between recorded instruments (i.e. electric guitar, bass guitar, saxophone, drums and synthesizer) was desired. The choir was recorded in "direct/ambient" perspective using four chosen multichannel techniques (INA 5, Corey/Martin Tree, Polyhymnia Pentagon and SoundField) as well as spot microphones. Surround techniques which are mentioned above, are presented later in this article. Then subjective quality evaluation is described, indicating the best rated multichannel technique and verifying a hypothesis about the impact of "direct-sound all-around" approach on the listeners' ability to distinguish between surround systems. Also, conclusions of subjective test results obtained are provided.

2. Multichannel microphone techniques

This Section discusses four multichannel microphone techniques such as: INA 5, Corey/Martin Tree, Polyhymnia Pentagon and SoundField that were employed in the recording.

The first one mentioned above, namely INA, is an acronym for German "*Ideale Nieren Anordnung*", which means ideal cardioid arrangement. The INA 5 microphone technique is based on the system proposed during the 108th AES Convention in Paris (Theile, 2000). The INA 5 configuration extends the three-channel INA 3 system for surround recording by adding two surround channels LS (Left Surround) and RS (Right Surround). The additional channels allow the producer to record reflections and reverberations characteristic for the room in which the recording is made. The placement of the microphones in INA 5 system is shown in Fig. 1. Front microphones: left, central and right, set up INA 3 multichannel technique for the recording angle $\varphi = 180°$. The distance between L-C-R triangle arrangement and added surround microphones is calculated according to "Williams-Curves" (Williams, 1984; 1999; 2000; Theile, 2001a, b). This ensures consistency between three recording areas (left, right, in the rear). Each recording area covers the recording angle $\varphi = 60°$. In addition, surround cardioid microphones with the technique mentioned are not facing backwards and the off-center angles are $\varepsilon = 150°$. The entire microphone setup guarantees the recording angle $\varphi = 360°$ for surround imaging (Theile, 2001).

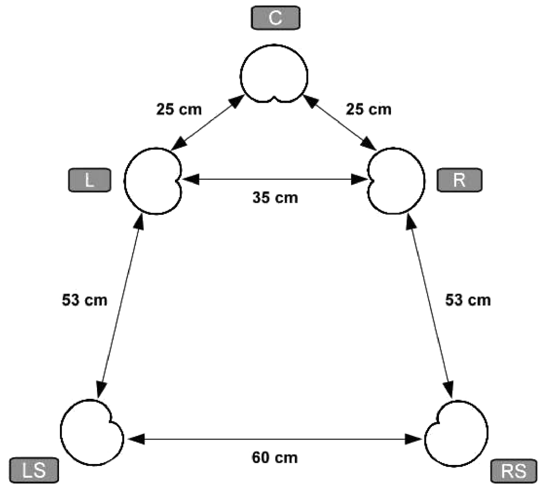

Fig. 1. Microphone placement in the INA 5 system.

Due to the wide recording angle of the front microphones, the INA 5 technique should be placed in a very close distance to the ensemble, for example over the conductor's head in order to capture a realistic instrument placement on the sound stage created by L-C-R speakers. This location is not correct if it comes to the surround microphones, as they would capture direct sound that is too intense from sound sources located at the sides of the orchestra. On the other hand, if the INA 5 is located optimally for correct surround channels recording, the orchestra will be perceived as being more or less focused in the center channel. It is described as the "center effect" (Theile, 2001a).

A paper by Corey and Martin, originally published online at http://www.dpa-microphones.com and then presented at the 24th International Conference of the Audio Engineering Society in Banff, Canada, introduced a new 5-channel microphone array technique (Corey, Martin, 2003; 2004; Martin, 2009). As stated by the authors, the main idea behind a 5-channel microphone technique is to capture the entire acoustic sound field, rather than to simply present the instruments in the front and the reverb in the surrounds. Spacing between microphones is determined by the desire to reduce/eliminate the comb filtering problem. The microphone array must ensure that the signals produced by pairs of loudspeakers are different enough to not create an interference pattern. The most effective way to achieve it is by separating the microphones. However, the signals should be similar enough to ensure the sound image continuity or fusion between channels.

Therefore, as a consequence the Corey/Martin Tree technique was created to ensure adequate separation between specific pairs of microphones. This is done to prevent inter-channel interference. This technique is also based on the response of the loudspeakers at the listener's position, which allows for achieving closer spacing, and hence provides a better sense of the sound field distribution for the rear pair of microphones (Martin, 2009). The system described consists of three subcardioids facing the front of the sound source, and two cardioids facing the ceiling (Corey, Martin, 2003; 2004). The typical distance between L-C and C-R microphone pairs is 60 cm and 30 cm between surround cardioids. The front microphones are usually spaced 60 cm from the rear pair. In addition, the central microphone can be moved up to 15 cm forward of the line of the Left and Right microphones (Corey, Martin, 2003; 2004), if necessary. Moreover, distances can be adjusted. The spacing of the front of array depends on the width of the recorded ensemble. It can also depend on the desired level of coherence between significant channels. For smaller ensembles, 120 cm spacing is desired, while for larger ensembles it may be necessary to increase the distance up to approximately 180 cm. The wider the tree is spaced, the more incoherent the three front channels are, which results in incoherence of sound image reproduced by L-C-R speakers. By changing the distance between front and rear microphones, it is possible to affect the consistency of front and rear sound images (Martin, 2009). It is often suggested that the microphone array and especially this technique allows for a large listening area in the reproduction system. Even when a listener is seated behind the sweet-spot, the front image of the direct sound will remain in the front and will not be pulled to the rear, despite the listener being closer to the rear loudspeakers. The location of the microphones in this system is presented in Fig. 2.

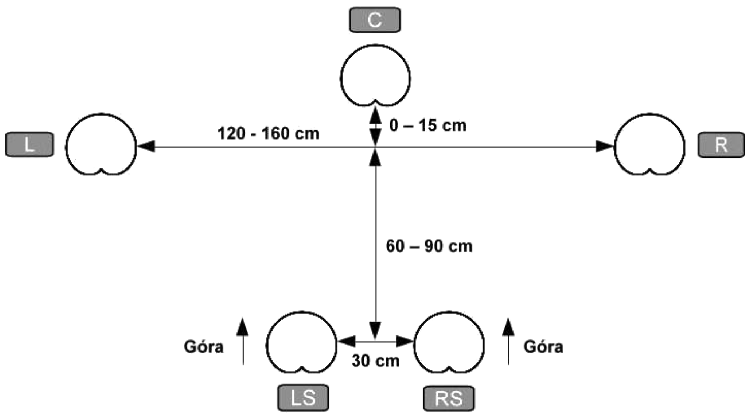

Fig. 2. Microphone placement in the Corey/Martin Tree system.

The Polyhymnia Pentagon is a surround microphone array invented by a Dutch recording and post-production studio – Polyhymnia International (formerly Philips Classics Recording Department). It is based on five widely spaced omnidirectional microphones (Peters, 2007). These microphones are arranged in a circle (approximately a 3 m radius). Figure 3 illustrates microphone location in the Polyhymnia Pentagon technique, in which the position corresponds to the azimuthal angles of the speaker in the ITU-R BS.775-1 recommendation (ITU, 1992).

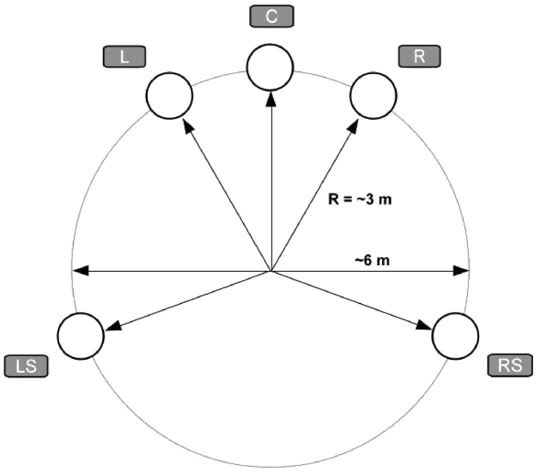

Fig. 3. Microphone placement in the Polyhymnia Pentagon system.

The signal recorded by each microphone is later panned into a corresponding speaker from this recommendation. This technique is often described as a multichannel version of the Decca Tree system. The angle between both L-C and C-R microphones is 30° and the LS-C and C-RS angles may be in the 100–120° range (Peters, 2007). The most common setting uses 110° angle between these pairs of microphones. The length of the radius can be modified depending on the ensemble being recorded, as well as the size of a room (for example, the recording performed used the Polyhymnia Pentagon with microphones arranged on a 2 m radius).

The fourth microphone technique employed in the recording, namely the SoundField system, is a multi-capsule microphone and a decoding processor separated from the microphone. These devices may be separated up to 100 m. The SoundField microphone forms the practical basis of the Ambisonics system (Gerzon, 1975) that can provide complete periphonic sound reproduction. The SoundField microphone captures the sound field through a tetrahedral array of 4 (near-) cardioid capsules. These sub-cardioid capsules are placed as close as possible in the compact design, which eliminates phase problems that are characteristic for spaced microphone arrays. Output signals of the capsules are known as A-Format. Then these signals are decoded in the associated unit (for example ST350 or SPS422B) into the so-called SoundField B-Format. All four components carry the entire information about the sound field around the microphone. Channels X, Y and Z describe the space in three dimensions: X – front/back, Y – left/right and Z – up/down. This is information about the gradient of acoustic pressure. The fourth channel – W – carries the omnidirectional pressure information about the sound field. This signal is a reference for other channels. The SoundField B-Format may be decoded either by separate hardware or a DAW-compatible plug-in into various surround formats.

3. Recording

A gospel song entitled "Seraphins, Cherubins" performed by the Choir of the St. Franciscan Cultural Center in Gdynia (see Fig. 4) together with an accompanying band was recorded during a two-day recording session (Sitek, 2010). The band consists of an electric guitar, bass guitar, synthesizer, saxophone and drums. The recording took place in the S-3 Concert Studio of Radio Gdansk. The band was only recorded with spotlight microphones to ensure the best possible separation between instruments which was desired for specific microphones. The separation made it possible to place sound sources into any channel in the surround panorama, what was necessary in order to create the assumed "direct-sound all-around" perspective. During the first session 20 tracks were recorded.

Fig. 4. Choir of the St. Franciscan Cultural Center in Gdynia during the recording session.

The choir was recorded using not only the four multichannel techniques mentioned above but also spot microphones. Figure 5 shows the placement of the Choir and microphone surround techniques. In addition, microphone placement of INA5 and Corey/Martin Tree surround techniques are shown in Fig. 6. Because various multichannel systems were used, this made it possible to choose the

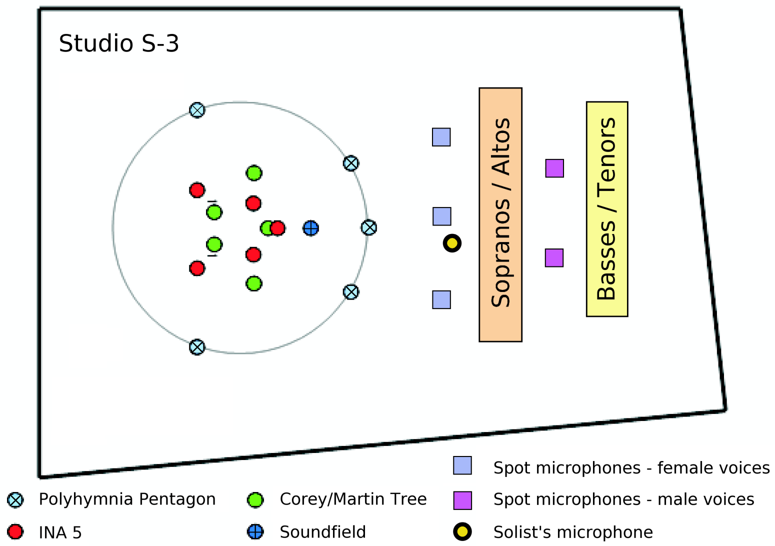

Fig. 5. Placement of the Choir and microphone surround techniques.

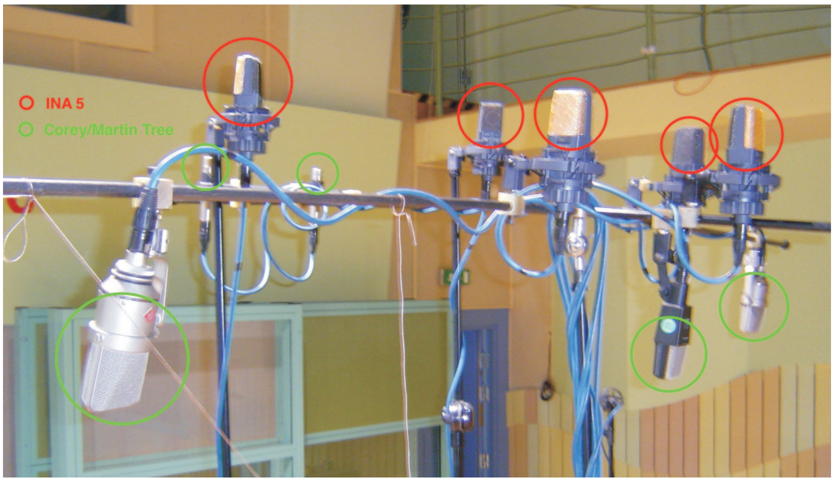

Fig. 6. Placement of INA5 and Corey/Martin Tree surround techniques.

one technique that was the most compatible with the mix of the band recorded. This choice was made on the basis of the conducted subjective quality evaluation. During the second day session, 19 tracks from four multichannel techniques and six from spot microphones were recorded.

The post-production of the recording was performed in the S-3 Studio control room in Radio Gdansk. First, all sound sources of the band were placed in surround panorama. After setting a correct balance between these sources and correcting their timbre, choir channels of the chosen multichannel technique

(Polyhymnia Pentagon) were added into the mix. Then, delayed sounds from spot microphones were added in order to color the timbre of the choir and to establish a better balance between voices. Instrument placement in surround image is shown in Fig. 7.

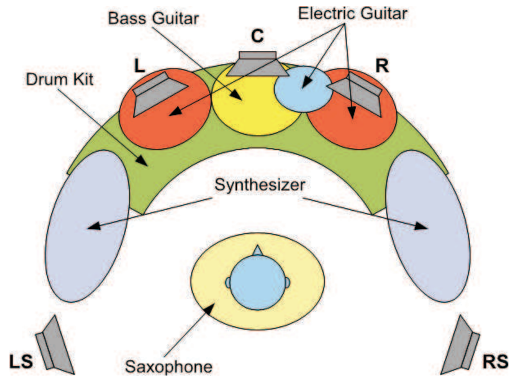

Fig. 7. Instrument placement in surround image.

4. Subjective quality evaluation

In this Section the subjective quality evaluation conducted on the basis of the recorded material is described. The aim of this evaluation was to choose the best rated multichannel technique and to verify the influence of "direct-sound all-around" approach on the listener's ability to differentiate between and to rate employed surround systems (recorded in "direct/ambient" approach).

A very thorough review of subjective evaluation procedures may be found in Bech's and Zacharov's book (2006). They recommend various techniques of testing along with statistical analyses that are useful in judging the results obtained in such tests. However, the most popular and easy to use non-parametric method for sound quality testing is the paired comparison test. The goal of this method is to compare objects, ordered in pairs, with each other and then to assess them on the basis of a two-level (better/worse) attribute scale. Technically, signal samples are presented in AB or (12) order. The experts' task is to choose the better one from a pair of sound samples that differ in acoustic features. The result is that a certain number is assigned to each compared sound sample which reflects the experts' preference (number of cases when the object won i such comparisons). In order to obtain reliable results, this method requires an appropriate number of tests and a statistical analysis of the results (e.g. chi-square statistics) (Kostek, 1999).

The application of statistical analysis for dealing with empirical data is aimed first of all at revealing the significance of differences among the objects being tested. The basic idea is to verify statistical hypotheses. First, the null hypothesis, to be verified later, has to be formulated.

The chi-square statistics χ^2 is defined as follows (Kostek, 1999):

$$\chi^2 = \sum_{i=1}^{r}\sum_{j=1}^{s} \frac{\left(n_{ij} - \dfrac{n_i \cdot n_j}{n}\right)^2}{\dfrac{n_i \cdot n_j}{n}}, \qquad l = (r-1)\cdot(s-1) \tag{1}$$

where l – number of degrees of freedom, r – number of test series performed, s – number of objects under test, n_{ij} – the number of events that are included in the i-th series of a test and the j-th object (number that denotes how many times the j-th object has been chosen in the i-th series of a test), $n_i = \sum_{j=1}^{s} n_{ij}$ – the number of events in the i-th series of a test, $n_j = \sum_{i=1}^{r} n_{ij}$ – the number of events that occurred with the j-th value, $n_i = \sum_{i=1}^{r}\sum_{j=1}^{s} n_{ij}$ – the total number of events.

If the null hypothesis is true, then the value for the chisquare statistics should be small, not exceeding the critical part of the distribution that is defined as:

$$P(\chi^2 \geq \chi^2_\alpha) = \alpha. \tag{2}$$

In the above defined approximation (2), α is the significance level. If the value of the measured statistics exceeds the value for (found in statistical tables) at the assumed significance level α and degree of freedom, then the null hypothesis is no longer valid and might be disproved with the probability of taking the false decision into account equal to α in favor of the alternative hypothesis.

A subjective quality evaluation was comprised of two A-B pair-wise comparison tests. Each test had the same structure: in two series, six pairs of audio signals were presented in random order. 15-second long audio signals were presented after a 2-second gap. Consecutive pairs were separated with 5 seconds of silence. The second series was presented after approximately two minutes. Audio was played back from the prepared DVD-Audio disc in order to provide the highest quality possible without any lossy compression. Both tests were based on the same part of the recording – the transition between the verse and the chorus. The chosen excerpt has a noticeable difference in the overall dynamics, thus the experts were provided with a more diverse sound image of the specific multichannel techniques (Sitek, 2010).

The subjective quality evaluation was performed in audio/video laboratory of the Multimedia Systems Department of the Faculty of Electronics, Telecommunications and Informatics at the Gdansk University of Technology. The 5.1 playback system was properly calibrated before the listening tests took place. The aim of the first test session was to check the ability of subjects to evaluate the surround techniques contained in a mix of instruments placed in "direct-sound all-around" perspective and the choir recorded by surround microphone techniques. A group of 30 subjects consisting of staff of the MSD and students of the Sound and Vision Engineering specialization participated in the first test. The second test was conducted about one week later with 29 experts from the same group (1 person was not available during the 2nd series). Excerpts presented to subjects in test No. 2 consisted of surround techniques, only.

Results of conducted tests were then analyzed correspondingly to the type of the test based on the statistical analysis. The following steps were performed during the analysis (Sitek, 2010):

- number of votes of each expert for each individual object was summed up;
- the stability of all experts was checked (z_1 parameter refers to the number of errors made by each expert);
- number of votes of all experts for each individual object was summed up;
- the χ^2 statistic was conducted to compare results of both series of the test;
- the number of experts who interpreted a given pair differently, depending on the part of the test was determined (z_2 parameter);
- the significance of differences between objects forming a given pair was examined at the assumed significance level (z_3 parameter).

The stability of experts (parameter – z_1) is examined by counting the number of different votes in the same pair for both series of the test and comparing this number with the critical value of the so-called sign test. The significance level was assumed at $\alpha = 0.05$ in the conducted test. This meant that experts were not allowed to make any mistake in order to be classified as "stable". The χ^2 statistic provides information if the differences of experts' votes in both parts of the test are statistically important, by comparing the calculated value with the critical value for this test χ^2_a. This value equals 7.82 for the significance level $\alpha = 0.05$ and for three degrees of freedom.

The sum of votes assigned by experts to each individual multichannel technique along with the division of votes to two series of test No. 1 is shown in Table 1. These results are also illustrated in Fig. 8.

As mentioned before, the second test presented only "direct/ambient" signals from microphone techniques and the results of this test are shown in Table 2. These results are also illustrated in Fig. 9.

Figure 8 shows that the best rated multichannel technique in test No. 1 was the Corey/Martin Tree. In this test the SoundField system received the least votes from the experts. It can also be noticed that the INA 5 and the Polyhymnia Pentagon received almost the same number of votes. Results of test No. 2 shown in Fig. 9 indicate the Polyhymnia Pentagon as the best rated multichannel

Table 1. The sum of experts' votes assigned to each multichannel technique in the first test.

	INA 5	Corey/Martin Tree	Polyhymnia Pentagon	SoundField
Sum of votes	88	113	99	60
I Part	47	50	50	33
II Part	41	63	49	27

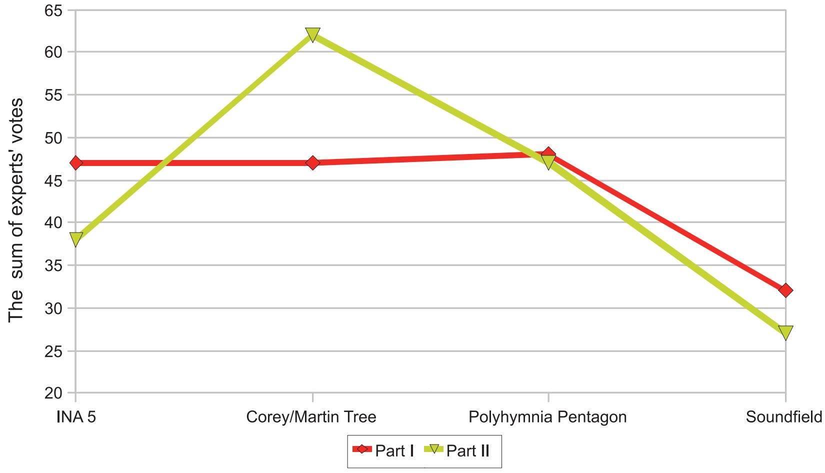

Fig. 8. The sum of votes cast by individual experts in two series of test No. 1.

Table 2. The sum of experts' votes assigned to each multichannel technique in the second test.

	INA 5	Corey/Martin Tree	Polyhymnia Pentagon	SoundField
Sum of votes	82	105	134	27
I Part	43	47	70	14
II Part	39	58	64	13

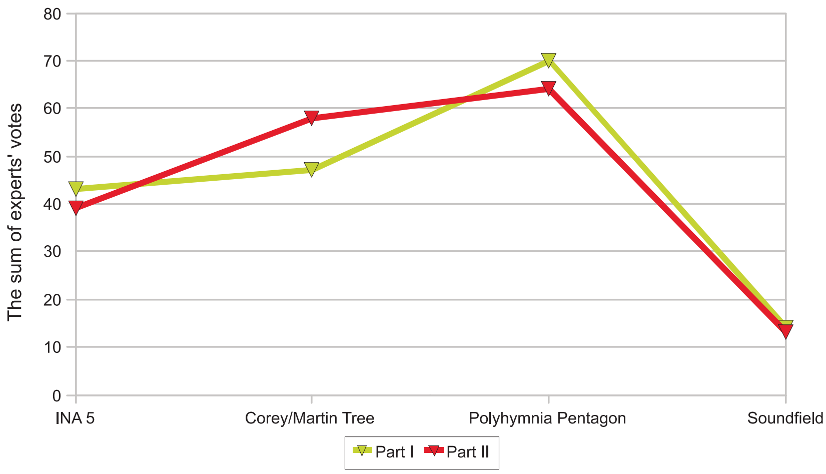

Fig. 9. The sum of votes cast by individual experts in two series of the test No. 2 (Sitek, 2010).

technique. Similarly as in test No. 1, the SoundField was consequently rated as the worst system. SoundField was the only coincident system among the chosen surround techniques, what indicates that for the purpose of surround musical recordings, it is more appropriate to use space microphone arrays.

Moreover, it was shown that experts had more difficulties in differentiating between surround microphone techniques presented along with the "direct-sound all-around" band in the background. In this situation the stability of experts was very poor and it became more difficult for them to differentiate between techniques. It is also noticeable that experts might consider different factors when choosing the best rated multichannel techniques, as different systems were chosen in both tests.

5. Conclusion

The study shows a subjective assessment of four multichannel surround systems (INA 5, Corey/Martin Tree, Polyhymnia Pentagon and SoundField) employed while recording a choir. Some details of the surround music recording session in Radio Gdansk were discussed. Then, the description and the results of the subjective quality evaluation were provided. The obtained results of the paired comparison test show that mixing together "direct-sound all-around" and "direct/ambient" approaches results in difficulties to differentiate between various multichannel systems as well as it changes the criteria of choosing the best quality technique. This could be caused by a difference in spatial envelopment very important in multichannel recordings. Also, another possible explanation is that the subjects, when listening to the mix of the band and the choir, had slightly different preferences than when listening to the choir itself.

Based on the tests performed it was noticed that it would be valuable to perform in the future a perceptual evaluation of various quality attributes across different listening positions. Such a study may answer the question of whether different microphone techniques affect the size of the sweet spot in a 5.0 multichannel sound system (Peters *et al.*, 2007).

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