

A History of the Development of Multichannel Speaker Arrays for the Presentation and Diffusion
Acousmatic Music

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I. Introduction

Throughout history, composers have been interested in the concept of spatializing and moving sound. The practice of spatialization can be traced to as early as the late 16th century with Venetian polychoral music of Gabrieli and Heinrich Schutz's *Musikalische Exequien*, which utilized a double choir, one positioned above the other for vertical spatial relationships between the voice parts. However, the most expansive exploration of spatialized sound can be found in electroacoustic and acousmatic music of the 20th and 21st centuries. Composers of electronic music began experimenting with various speaker positions and configurations, changing the total number of speakers utilized in a performance, alteration of the performance practice of diffusing sound in a real time and have developed numerous software and hardware applications specifically for the advancement and further development of manipulating listening spaces in the experience of fixed and live electronic music. This paper will explore some of those experiments in a brief historical survey of the development of various speaker arrays, the philosophies and aesthetics behind those developments, a discussion of performance techniques of sound diffusion and how the practice of spatialized sound can be related to both concert works and the entertainment industry.

Before moving forward with any discussion of multichannel systems, one must first be familiar with some of the tangential concepts associated with the aesthetics and philosophy that drove composers to develop multichannel speaker arrays. Arguably the most important of these concepts is the idea of approaching the loudspeaker as an instrument. A loudspeaker is, afterall, a device whose primary function is to transmit sound waves that are diffused into the open air, similar to any traditional musical instrument. Additionally, the electrical signal sent to the loudspeaker controlling the frequencies and amplitudes of the sonic output can be manipulated and controlled in real or fixed time. In this way, the speaker can be approached in the same manner a composer might approach an oboe,

violin, or percussive instrument. This idea of approaching a speaker as an instrument with unique characteristics and tone will be revisited in this paper, but at this point, in the context of this paper, it suffices to say that when referring to loudspeakers one should consider it analogous to working with musical instruments.

It is also important that one understands the historical and geographical origins of multichannel speaker arrays. In 1948 Pierre Schaeffer, a telecommunications engineer working at *Radiodiffusion-Télévision Française* (RTF) began experimenting with manipulations of recorded sound along with his colleague Pierre Henry. These were the beginnings of what Schaeffer would eventually refer to as *musique concrete*, a style of composition in which composers were working with the concrete materials of sound (frequency, amplitude, phase, etc.),¹ and it was out of this practice that a deeper fascination with the idea spatial relationships of sonic images began to emerge. The majority of large multichannel projection of electronic music can, in some way, be traced to the early experiments of Schaeffer and his colleagues.

II. History and Developments of Multichannel Arrays

IIa. Early Developments in France and Germany

The earliest practices of multichannel sound diffusion in electronic music can be traced to 1951 with the Pierre Schaeffer, Pierre Henry and other composers of *musique concrete*. Early concerts presented pieces in a fixed format, but in 1951, Schaeffer and Henry introduced the *potentiomètre l'espace*, developed by Jaques Poullin, pictured in Figure 1.² The practice of *musique concrete* began

¹ Jonty Harrison, "Sound, space, sculpture: some thoughts on the "what," "how," and "why of sound diffusion," *Organized Sound* 3, no. 2 (1998): 117.

² Harrison, "Sound, space..." 118.

with capturing recorded sounds and reproducing pieces on turntables (the seminal concert being the joint composition *Symphonie pour un homme seule*), but the *potentiomètre l'espace* utilized recordings on magnetic tape separated into five discrete tracks that could be diffused to four speakers placed throughout the room. The speaker configuration consisted of two speakers in front of the audience - one left and one right - speaker three in the rear center of the audience and speaker 4 speaker in the ceiling projecting sound downward. Tracks 1-4 would be sent to the corresponding speaker number (track 1 to speaker 1, track 2 to speaker 2...) and the fifth track could be sent dynamically to any one of the speakers. It should be noted that the date of this particular development in the practice of electronic composition is important as it demonstrates that composer of *musique concrete* became interested in the concept of manipulating spatial relationships of sound within the first few years of the genre's creation in 1948. The use of the *potentiomètre l'espace* continued to dominate *musique concrete* performance until further developments in sonic spatialization were made in the 1970s, a topic that will be covered in greater detail in section IIb.

A later development of multichannel composition can be found in Karlheinz Stockhausen's landmark electronic work *Gesang der Junglinge* composed during 1954-55 and presented in 1956.³ The speaker array of Stockhausen's work is similar to that used in Schaeffer's and Henry's *potentiomètre l'espace*, but with an added rear speaker to create a more defined quadraphonic surround sound image. One could postulate that Stockhausen was influenced by the *potentiomètre l'espace* considering the time he spent at the *Groupe Recherche Musique Concrete* (GRMC) in 1952 studying the *musique concrete* style of Schaeffer, Henry, et al. It is reasonable to believe that he had experience

³ Curtis Roads, *The Computer Music Tutorial* (Cambridge , MA: MIT Press, 1996), 453.

with the multichannel tape diffusion practices and expanded that practice upon his return in March 1953 to the Westdeutscher Rundfunk (WDR) in Cologne to work with Herbert Eimert.⁴

While the creation of the *potentiomètre l'espace* is an important development in the history of electronic music and of multichannel systems, the most significant early development in multichannel arrays took place in 1958 at the World's Fair in Brussels, Belgium with the creation of Le Corbusier's Philips Pavilion. Le Corbusier was approached by the Phillips Electronics company in 1956 and asked to construct a building to host the 1958 World's Fair. With the help of composer and architect Iannis Xenakis - a composer also associated with the practice of *musique concrete* in Paris in the 1950s - the two designed the uniquely structured Pavilion, shown in Figure 2, and the Philips company installed an array of 425 loudspeakers around the building. Philips then commissioned the French composer Edgard Varese to compose a new work of electronic music which would later be titled *Poeme Electronique*, to be diffused throughout the 425 loudspeakers, along with Xenakis' own composition *Concrete-PH II*, for all attendees at the World's Fair to experience.⁵ This was not only a major achievement of architecture, but also a significant development in the philosophy and practice of sound diffusion, presentation and performance of electronic music. The work of Le Corbusier, Xenakis and Varese would (and still does) continue to impact how composers of electronic music think about the spaces in which acousmatic music is presented and the impact that a space has on a listener's interpretation of the work.

⁴ Richard Toop. "Stockhausen, Karlheinz." *Grove Music Online. Oxford Music Online*. Oxford University Press, accessed April 7, 2016, <http://www.oxfordmusiconline.com.ezproxy.lib.utexas.edu/subscriber/article/grove/music/26808>.

⁵ "The Electronic Century Part II: Tales of the Tape," by Joel Chadabe, *Electronic Musician*, last modified March 1, 2001, accessed April 6, 2016, <http://www.emusician.com/gear/1332/the-electronic-century-part-ii-theses-of-the-tape/32014>

IIb. Ongoing developments throughout Europe and North America

Following the success of Xenakis' and Varese's performances at the 1958 World's Fair and the ongoing experimentation of spatialized sound by Stockhausen in Cologne numerous composers became more interested in the practice of spatialized music on systems beyond a two-channel stereo setup. In the United States John Chowning, a composer and professor at Stanford University, became interested in the idea of placing audio signals in discrete channels to manipulate physical listening space. Chowning was also interested in the psychoacoustical phenomenon of frequency-dependent localization, specifically in relation to reverberation and the rising and falling of Doppler shift.⁶ Chowning adopted Max Matthews' MUSIC V system, and with the assistance of software developed by David Poole and Leland Smith, Chowning created Stanford's Music 10 software, capable spatializing sound on four-channel tape that could be sent to any one of four discrete loudspeaker locations. Additionally, he was able to manipulate the psychoacoustic perception of a sound's location and place it outside of a square perimeter, wherein the four loudspeakers would be placed at the four corners of said perimeter, all facing inward at a 45° angle. Chowning achieved this degree of spatialization through the combined Music 10 software developed during his research with Poole and Smith and through the manipulation of frequency-based psychoacoustical phenomena, namely reverberation characteristics and Doppler shift.⁷ The final produce of Chowning's research in sound spatialization was his compositions *Turenas* in 1972 and *Sabelithe* completed in 1988.⁸ This was the first instance of a composer sending audio signals to any number of discrete loudspeaker channels to achieve lateral and radial motion of sound. A graph of this motion is shown in Figure 3.

⁶ John Chowning, Transcript of "*Turenas*, the realization of a dream," paper presented at Journées d'Informatique Musicale Université de Saint-Etienne, May 2011, 2.

⁷ Chowning, "*Turenas*..." 2-3.

⁸ John Chowning, "*Turenas* and Its Innovations," *eContact!* 12, no. 2 (April 2010): 2.

Composers in also France continued exploring innovations in spatialization, with the development of new forms of sound diffusion and multichannel speaker arrays. Francois Bayle, a former Student of Pierre Schaeffer, Olivier Messiaen and Karlheinz Stockhausen, took over as the director of GRM in 1966. As the director he remained active as a composer and music theorist with his primary focus being electronic and electroacoustic music. It was during this time that Bayle coined the term *acousmatic music*.⁹ In 1974 Bayle created the Acousmonium, an “orchestra of loudspeakers,” in which Bayle constructed a large array loudspeakers varying in size, power and frequency response. Images of the Acousmonium are shown in Figures 4a and 4b. The speakers were often formulated in pairs around the stage and surrounding the audience, with careful placement and attention given to the location of a speaker or pair of speakers in relation to its relative amplitude and frequency response.

For Bayle it was essential that the Acousmonium be thought of as a single instrument with numerous voices. It was important that the Acousmonium be constructed with different types of loudspeakers, and even with different speaker configurations that would establish new spatial relationships for each concert and even each piece.¹⁰ The loudspeakers could be divided into two categories, “wide-band” loudspeakers that could reproduce the entire frequency spectrum, and “colored” loudspeakers that had a shaped frequency response or some degree of external frequency filtering.¹¹ The idea was that the Acousmonium would allow a composer to actually orchestrate a fixed

⁹ Francis Dhomont. "Bayle, François." *Grove Music Online. Oxford Music Online*. Oxford University Press, accessed April 7, 2016, <http://www.oxfordmusiconline.com.ezproxy.lib.utexas.edu/subscriber/article/grove/music/02386>. It should also be noted that Bayle was not the first to use the term acousmatic. It was originally used in a 1955 article by Jean Peignot titled “De la musique concrete a la acousmatique” published in *Espirit*. The term was also used by Pierre Schaeffer, however Schaeffer and Peignot used the term in reference to the sound objects and the creation of music using loudspeakers in which the original of the sound is unknown. Bayle was the first to use the term as a description of the genre in which he, and other like-minded composers of music on fixed electronic media, were practicing during this period of time. This topic was covered in some detail in the introduction of this paper, but should a

¹⁰ Elizabeth Anderson, “An Interview with Annette Vande Gorne, Part 2,” *Computer Music Journal* 36, no. 1 (Spring 2012): 13.

¹¹ Jonathan Prager, “à l'interprétation acousmatique,” Lyon, 2002 booklet published for the courses he runs in France, Italy and Japan. 10, 15.

composition. A piece that consisted of two channels of audio could be sent to any number of channels of the Acousmonium via the diffusion console, but depending on the speakers utilized the color of the sound would be altered as a result of filtering and differing frequency response.

A third important development in the history of multichannel loudspeaker systems is the Birmingham ElectroAcoustic Sound Theater, or BEAST, established in 1982 by Jonty Harrison, who acted as the director until 2015. The BEAST setup is in some ways similar to the construction of Bayle's Acousmonium, in that Harrison constructed the BEAST with the idea of using pairs of speakers (though the entire construction does not consist of paired speakers), utilizing loudspeakers with variation in frequency response and power, and the system is variable in that a composer may choose to utilize all or part of the system. The overall structure of the BEAST rests on the shoulders of eight main speakers, sometimes referred to as the BEAST main eight.¹² These are a two pairs of front speakers, one wide pair and one centered pair forming an arc in front of the audience and acting as the "Main" pairs, shown in Figure 5a. These speakers are of the same frequency response and are powered by the same amplifiers as a means of matching their tone and color as closely as possible. Another pair of speakers sits at the back of the stage, the left being placed halfway between the wide and center left, the right being halfway between the wide and center right. This pair acts as the "Distant" pair, and are suspended above ear-level and are angled inward toward the center. This maintains the stereo image created by the main speakers, but offers the listener a sense of psychoacoustical distance. The final pair are positioned at the rear of the audience and are also suspended above ear-level, facing inward at an angle of 45°. In addition to the main array of eight speakers surrounding the audience, ostensibly

¹² Jonty Harrison, "Diffusion: theories and practices with particular reference to the BEAST system," *eContact!* 2, no. 4 (September 1999) 5-6. All discussion of the construction of the BEAST herein is taken from Harrison's 1999 *eContact!* article referenced here. Harrison goes on to discuss the various positioning of the main eight speakers of the BEAST system and talks to some degree about the additional speakers placed around the space and suspended overhead. All discussion of specific construction is taken from this article.

arranged to transmit stereo imagery, the BEAST system has a number of speakers placed around the listening space, all of which have differing frequency response, angle, directionality (facing toward or away from the audience), and vertical suspension. The result is a multichannel array of 100 loudspeakers (Figure 5b), which is in a fixed position, but gives the composer numerous opportunities to transmit their music into a listening space and manipulate the listener's experience via the site-specific construction of the array.

IIc. Recent Developments - Stockhausen, UIUC and the Discrete Eight Setup

The development of the Acousmonium and the BEAST gained popularity with composers throughout the last quarter of the 20th century and numerous concerts were held wherein acousmatic music was presented on these systems, and the instruments themselves underwent various developments in number and arrangement of loudspeakers. One development was a strong focus on quadraphonic and octophonic setups as a means of achieving immersive surround sound, similar to the work done by Chowning in the 1970s. The difference between this approach and the Acousmonium or BEAST is that these quad- and eight-channel setups used evenly spaced loudspeakers of the same quality and frequency response to achieve a uniform quality of sound throughout the listening space. An early and significant work of this nature is Karlheinz Stockhausen's *Oktophonie* from 1991, in which the composer used two arrays of four loudspeakers in a 3-dimensional cube around the audience. One array of four speakers was suspended above the audience and the other array was placed below the audience, with a speaker in each corner of the room, both top and bottom. This created a fully immersive sound laterally and vertically.¹³

¹³ Toop, Richard, " "Dienstag aus Licht ('Tuesday from Light')," *New Grove Online Dictionary of Opera*, Oxford University Press, 2008, accessed April 8, 2016, http://www.oxfordmusiconline.com.ezproxy.lib.utexas.edu/subscriber/article/grove/music/O2061713?q=oktophonie&search=quick&pos=2&_start=1#firsthit

Further developments in octophonic spatialization continued in the United States into the mid-to-late 1990s at the University of Illinois at Urbana-Champaign under the direction of Scott Wyatt. The university already had a rich history of being a center for electronic music in America, and was one of the first studios of its kind in the Western hemisphere.¹⁴ Composer Salvatore Martirano developed his Sal-Mar 24-channel hybrid synthesizer, and Herbert Brun expanded the language and practice of computer music and computer synthesis in the 1960s. However, it was in the 1995-8 that Scott Wyatt - along with graduate students Cris Ewing, J-C. Kilbourne, Paul Oehlers, Michael Pounds and Ann Warde - developed a system of eight discrete channels in a ring surrounding the audience. Wyatt referred to his setup as the Discrete 8 setup, and through extensive research into psychoacoustics and previous approaches to a multichannel system developed what would become the *Discrete 8* setup of Urbana-Champaign.

Wyatt and his students reviewed three basic setups for 8-channel diffusion and weighed the pros and cons of each setup before choosing what would become the UIUC Discrete 8 system. The first was a configuration of eight speakers in a ring around the audience. This would lend itself well circular motion and diffusion of mono signals, but the circular configuration would make true stereo imaging difficult. The second configuration was the main eight speakers of Jonty Harrison's BEAST setup, but this did not provide the immersive experience that Wyatt and his students were striving for, and while it was ideal for stereo imaging was not ideal for diffusion of mono signals. The final configuration was one in which three loudspeakers were placed in front of the audience (left, center and right), three behind the audience (left, center and right) and a pair of loudspeakers on the sides of the audience. This was modeled after the 5.1 and 7.1 systems utilized in film and entertainment and

¹⁴ Scott Wyatt, "Gestural Composition," *eContact!* 1, no. 2 (March 1998) 1.

would provide composers with three distinct stereo images in addition to front and center channels to fill out the overall immersive imaging Wyatt was striving for. Images of these speaker configurations can be seen in Figures 6a, 6b and 6c.

The 8-channel loudspeaker configuration was not new to Scott Wyatt's Discrete 8 setup, though. The use of the BEAST main eight speakers was an early take on the concept of multichannel diffusion using a large stereo image of eight speakers. In addition to the BEAST main eight, there are two other commonly used speaker configurations consisting of eight channels in a "ring" setup around the audience.¹⁵ One of these setups is the circular configuration mentioned above in Scott Wyatt's research, wherein eight discrete channels are placed in a circle with a front center and rear center channel. This is commonly referred to as the "double-diamond" setup. The other configuration is a ring setup in which four stereo pairs of speakers are positioned around the audience as front L-R, wide L-R, side L-R and rear L-R. This is referred to as the "shoe-box" setup, or more commonly in some circles as "big stereo" as it can present a stereo image in a circular fashion around the audience, though it could also be approached as eight discrete mono channels. Images of these configurations can be seen in Figure 7a and 7b. These configurations have gained popularity as speaker arrays within the United States, Canada and Europe, but it would be difficult to argue that either setup is standardized as "the" array for multichannel composition and/or diffusion performance.

III. Performance Practice and Considerations

IIIa. Presentation and Performance on Multichannel Arrays

Section II of this paper explored numerous configurations of speaker arrays that developed throughout the 20th century, and it is still by no means a comprehensive treatment of the history of

¹⁵ Jonty Harrison, "The Final Frontier: Spatial Strategies in Acousmatic Composition and Performance," *eContact!* 14, no. 4 (March 2013) 14-15.

multichannel systems. One can easily see that the approach to the construction of these systems varies greatly from place to place, and one of the main reasons for having differing setups has to do with aesthetic and philosophical leanings of the composers who are utilizing and building these setups. One of the primary considerations in working with a multichannel system is how the composer will approach the loudspeakers as individual instruments within the context of the greater meta-instrument configuration, and how this will be presented to an audience in real-time. One method is the practice of live sound diffusion, wherein a composer creates a stereo composition and using a mixing console, diffusion system or other means will distribute the left and right channels of the stereo signal to various speakers of the array. This can effectively create a sense of moving sound throughout a space, and can also give the composer control over the “orchestration” of his or her composition. In the discussion of Bayle’s Acousmonium and Harrison’s BEAST system it was mentioned that both systems utilized loudspeakers with varying power, dynamic range and frequency response. In the practice of live diffusion a composer could place the same sound in multiple loudspeakers around the space with different characteristics and the sonic output would be similar, but varied slightly in each speaker, essentially creating a manipulation of space and the psychoacoustical properties of the sound objects themselves.

The other method of multichannel composition would be to create all of the spatialization of sound in the studio. In this method, the composer considers the total number of loudspeakers in the configuration and composes a piece in which the distribution of sound will be the same in each performance and is entirely automated by sending multiple channels of audio from a distribution center (a central mixing console) to each of the discrete channels of the system. This method still allows the composer to orchestrate their sounds and gestures according to the characteristics of the speakers, but it

removes the element of live performance, and places greater importance on utilizing a specific speaker setup in which the type of signal going to each speaker is carefully controlled during the compositional process, and could potentially be very different types of sonic material from one speaker/audio channel to the next.

IIIb. Software and Hardware for Distributing Over Multichannel Arrays

The creation of multichannel acousmatic compositions is handled almost entirely in the studio with various types of hardware and software including, but not limited to, various digital audio workstations (DAWs), music coding languages (Csound, Max/MSP, Pure Data, SuperCollider) and stand-alone processing applications for various kinds of processing, all of which is wired to a central CPU and ADC/DAC audio interface. When the composition is complete a question arises of how the composition will be presented to the loudspeakers. Luckily, numerous advances have been made since the origins of multichannel arrays and composers and audio engineers now have numerous software and hardware tools for assisting in the presentation of fixed multichannel compositions and live diffusion.

The most obvious solution to the issue of outputting audio to a multichannel system is to play the audio back through a DAW, as this type of software is most likely where the composition was originally conceived. In the situation of fixed playback of a multichannel work (meaning the spatialization is predetermined prior to the concert) one could simply play the audio files - stereo or mono - for each individual loudspeaker or pair of speakers, output the signal from the interface into a mixing console and that audio is then distributed to the speakers. This same process can be used for live diffusion, but in this case only two channels of audio would be sent to the mixing console and those two channels of audio would be sent to the various loudspeakers (all left channels to “left”

speakers, right channel to “right” speakers, and any specially numbered channels the system might contain [center, suspended, etc.]).

Another solution to the issue of audio distribution is to create a custom diffusion and mixing program in a coding or patching language such as Max/MSP or Pure Data. This solution is useful especially in the case of an instrument like the Acousmonium which makes use of both paired and single speakers in a configuration that will at times change the physical location of speakers. With a program like Max/MSP the routing can be fully customized with pre-made “snapshots” to create, store and recall specific mixing configurations quickly without having to go through the trouble of building a DAW session and assigning/reassigning the channel/track output assignments for each piece or performance. Max/MSP and Puredata are also capable of MIDI input control, which would allow engineers and composers to use the customized software in tandem with a hardware MIDI control surface for live mixing and diffusion purposes. This could essentially act as a mixing and gain staging portion of the overall signal chain, with all audio eventually being sent to the house system or mixing console to distribute the signals at unity, giving the composer/diffuser full control over spatial diffusion from within the software environment. There are other solutions to the issue of mixing and spatialization, but because of the simplicity of the DAW and the modularity of custom-built mixing software with coding and patching languages, these methods have become widely used methods of distributing audio signals in multichannel environments.

IIIc. Considerations of Setup and Pragmatism

In going through the history and development of various loudspeaker configurations one can see that the only constant in these arrays and setups is the lack of standardization. This is a very important factor for composers to take into account when composing multichannel music. If one were

to composer a piece for the BEAST setup with fixed spatialization they would need to understand from the onset that this piece could only be performed accurately on the BEAST configuration. To take that same piece and perform it on the Acousmonium would require a rethinking of the materials used, as Bayle's philosophy of the Acousmonium as an instrument differs from Harrison's conception of the BEAST.

The same argument can be made for Scott Wyatt's Discrete 8 system. It was mentioned that Wyatt and his students labored over the decision of which configuration to use. This is an important decision to make, as a ring of eight equidistant speakers in a ring with front and rear center channels (the double-diamond) will provide a different overall sonic image than eight equidistant loudspeakers arranged in stereo pairs with no center channels (the shoebox). The double-diamond offers the composer better circular and radial motion around the space, but a more limited use of stereo pairs, and he or she would most likely want to work with mono recorded sound sources. The shoebox offers a greater sense of a large immersive stereo configuration, but the lack of center channels creates a very noticeable hole between the left and right semicircles of the configuration. One could not simply take an 8-channel composition for a double-diamond setup and present it on the shoebox and expect the same sonic result or spatial experience.

The lack of standardization also causes composers to create very site-specific compositions. In the same way that Varese's *Poem Electronique* was a site-specific composition for the Philips Pavilion, so are the compositions composed by Jonty Harrison for the BEAST. In order for Jonty Harrison to fully realize his stereo works with the diffusion originally intended he would have to construct a multichannel system that mimics what he has produced at BEAST, even if on a smaller scale.

IV. Multichannel Arrays in the Entertainment Industry, 5.1, 7.1 and the THX Standard

The research provided thus far has discussed multichannel systems for the presentation and performance of concert works in the acousmatic tradition that grew out of *musique concrete*. However, the origins of surround sound actually predate any of the developments discussed so far in this paper. The first example surround sound audio was a primitive 5.1 system developed by Disney for the film *Fantasia*.¹⁶ The setup created by Disney used stereo recordings of the orchestra distributed to front left, front center and front right channel, with the center channel being a blend of the left and right, possibly created using the Decca tree recording technique. The system also had rear left and rear right speakers that presented copies of the front left and right signals. This would later develop into the 5.1 and 7.1 standardization that would be used in home theaters and cinema theaters to surround the audience with audio. The front center channels are reserved for the audio tracks (except in the case of panned dialog), and the surrounding speakers are treated as discrete channels or stereo pairs for a fully immersive audio experience. The most significant aspect of this setup is that it quickly became standardized in practice. All 5.1 and 7.1 systems have the same speaker setup, the same angling of speakers (shows in Figures 8a and 8b) and all films, regardless of distribution company or location use the same formats and spatialization tools. This is further standardized by the creation of THX, a high-quality audio standard developed by Lucasfilm in 1983 with the release of “Star Wars: Return of the Jedi.”¹⁷ This audio standard, applied to speaker quality, frequency response, cables, spatial relationships of surround sound, etc. further solidified the standardization of surround sound audio systems in the entertainment

¹⁶ Michael Miller, “The History of Surround Sound,” updated September 24, 2004, accessed April 3, 2016, <http://www.quepublishing.com/articles/article.aspx?p=337317>

¹⁷ “The THX Story” from the THX official website, accessed April 4, 2016, <http://www.thx.com/about.php>

industry. The robust standardization of THX, affordability of 5.1 home systems, and cross-platform compatibility of audio to various hardware playback systems creates a system in which home theaters and cinemas can consistently present high-quality audio to audiences and make few developments in the actual configuration of the speaker arrays, which have developed very little over the last 30+ years.

V. Conclusions

The development of multichannel arrays since the construction of the Philips Pavilion in 1958 demonstrates the constant awareness and curiosity composers have had with spatialized sound imagery. Developments in the loudspeakers setups themselves, as well as software and hardware used to control the systems and the development of the live diffusion performance practice continues to develop as these speaker arrays continue to grow, change and expand. Though the primary focus of this paper was on the development of the Acousmonium, BEAST and variations on the Discrete 8 set up, numerous universities and organizations dedicated to the presentation of acousmatic and electroacoustic composition have started creating their own variations of multichannel arrays. Some of these include the 48-channel system HISS at the University of Huddersfield (UK), the 124 channel stacked circle construction of the “Cube” at Virginia Tech (US), the various multichannel arrays found at New Adventures in Sound Art in Toronto (Canada), as well as numerous universities around the world with one or more of the variations of the Discrete 8 system developed by Scott Wyatt. One of the largest current systems is the Allosphere of UC-Santa Barbara, a 3-story cube consisting of 140 loudspeakers plus subwoofers. The Allosphere is capable of reproducing an incredibly accurate 3-dimensional sound-space within a multimedia environment that is capable of various visual effects including lighting and 3-dimensional projection.¹⁸ The BEAST and Acousmonium also remain in use, the BEAST containing nearly 100 loudspeakers and Acousmonium containing more than 80

¹⁸ “The Allosphere Research Facility,” University of California - Santa Barbara, accessed April 8, 2016, <http://www.allosphere.ucsb.edu/>

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Figure 1: Pierre Schaeffer performing on the *potentiometre l'espace* in a 1951 performance in Paris.



Figure 2: The Philips Pavilion designed by Iannis Xenakis and Le Corbusier for the 1958 Brussels World's Fair. The Pavilion was fitted with 425 loudspeakers on which Varese's *Poem Electronique* and Xenakis' *Concrete-Ph II* were diffused to the audience during the event. This was the earliest and largest diffusion system created and acted as a front-runner of later multichannel arrays.

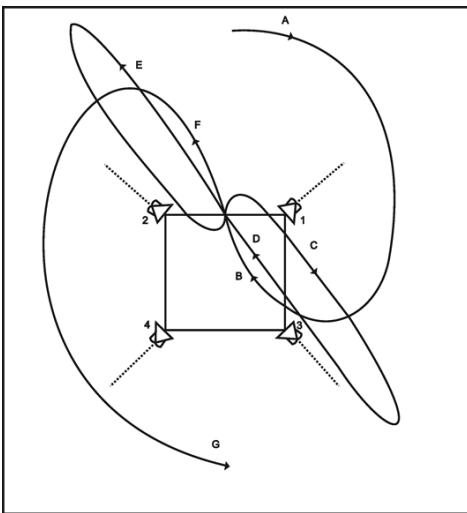


Figure 3: An diagram of Chowning's radial diffusion created using his MUSIC IV/Music 10 system. The system allowed for sounds to be diffused from four discrete channels of audio to four discrete speaker locations, allowing for the perception of moving sound, as well as distance cues. Sound could appear that it was coming from behind speakers and moving diagonally around the listening space. The system was based on frequency-based psychoacoustic effects such as reverberation and Doppler shift.

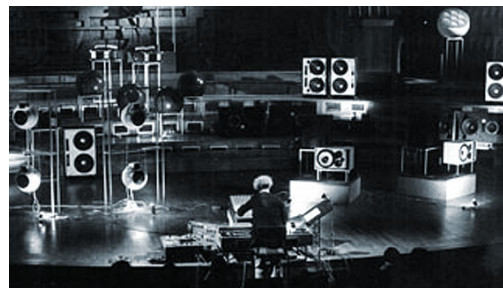


Figure 4a (above): Francois Bayle performing on his Acousmonium system. Notice that some speakers are arranged in pairs and other as individual speakers.



Figure 4b (below): Pierre Schaeffer introducing the Acousmonium at GRM in 1974. This figure provides a clearer image of speakers of similar power and frequency response grouped in pairs.

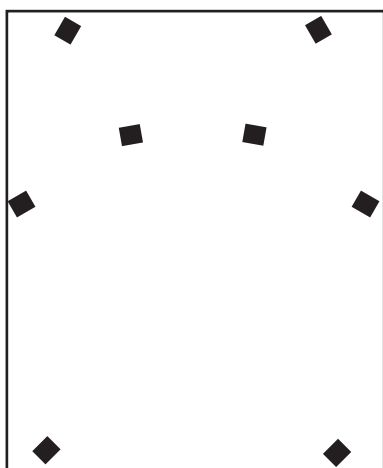


Figure 4a: The BEAST main 8 speaker setup. Speakers 1 and 2 are the near speakers at a ± 10 degree angle. Speakers 3-4 are the wide speakers at a ± 15 degree angle, 5 and 6 the Distant pair at a ± 60 degree angle and rear 7 and 8 pair as the surround pair at a ± 45 degree angle.

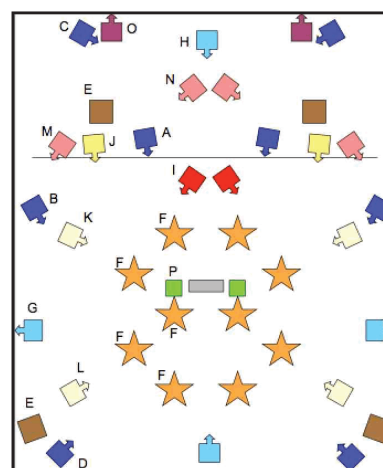


Figure 4b: A more complete diagram of the BEAST setup. Notice that all of the speakers are varying angles and some even face away from the audience, creating reflective sounds within the listening space. In addition to the speakers shown in this diagram there are also speakers suspended above the audience specifically for high-frequency content.

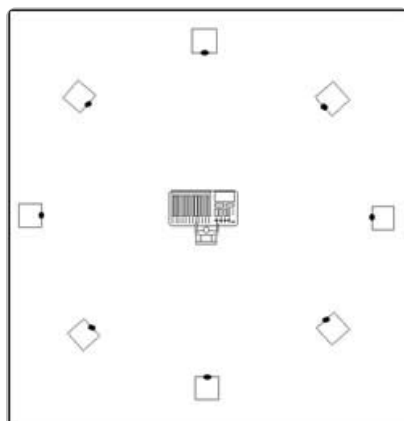


Figure 5a: The first 8-channel speaker configuration considered by Scott Wyatt for his Discrete 8 speaker setup. This configuration is ideal for transmitting mono signals and for creating circular motion, but is somewhat limited in creating a full stereo image in front and back. The use of center channels helps to fill out the circular image.

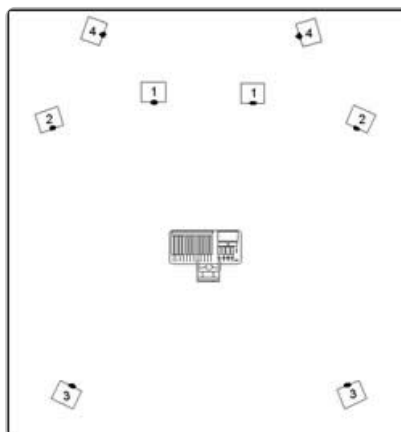


Figure 5b: The second configuration considered by Wyatt. Notice the similarity between this setup and the BEAST main 8 setup shown in Figure 6a, but with the wide pair closer to the front pair and distant pair.

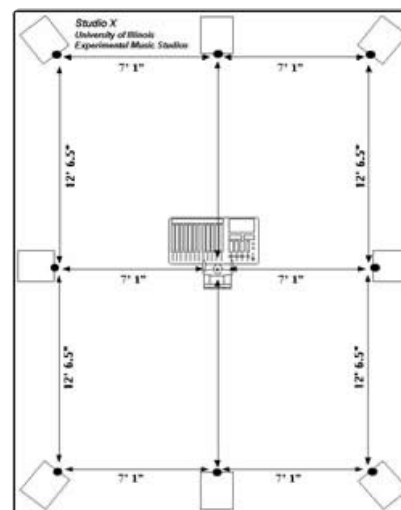


Figure 5c: The configuration ultimately chosen by Wyatt. This setup is similar to a 7.1 setup used in theater and film surround sound with an added center channel in the rear to fill out the image. This provides an accurate stereo image in the front, rear and sides while also filling out the center in front and back

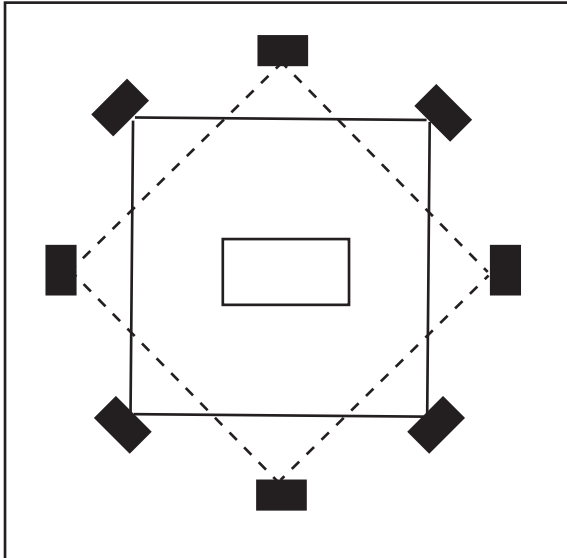


Figure 7a: The “double-diamond” setup, the same as shown in Figure 6a. Notice the two quadrilateral figures that are created by combining the front and rear speakers and by combining the center and side speakers. This is an ideal setup for creating circular diffusion with mono sound sources and for creating diagonal streams of audio across the diamonds.

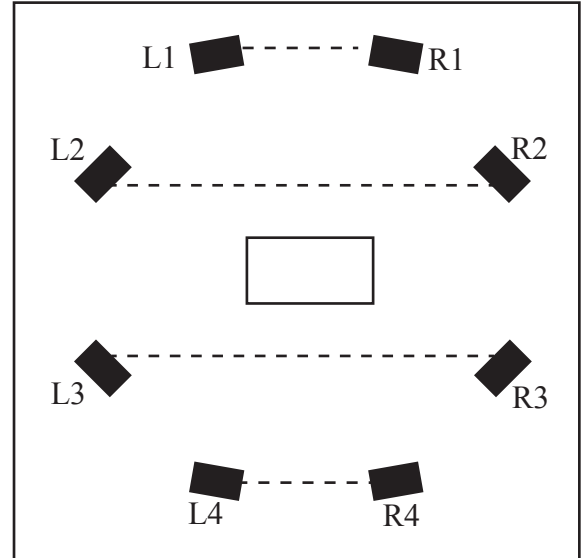


Figure 7b: The “big stereo” or “shoe-box” setup (as referred to by Jonty Harrison). This 8-channel setup provides a full stereo image in the front, rear, sides and a wide front pair. This is an ideal setup for diffusion of stereo pieces that desire to maintain a clear stereo image, but could prove unreliable for creating real-time circular diffusion patterns.

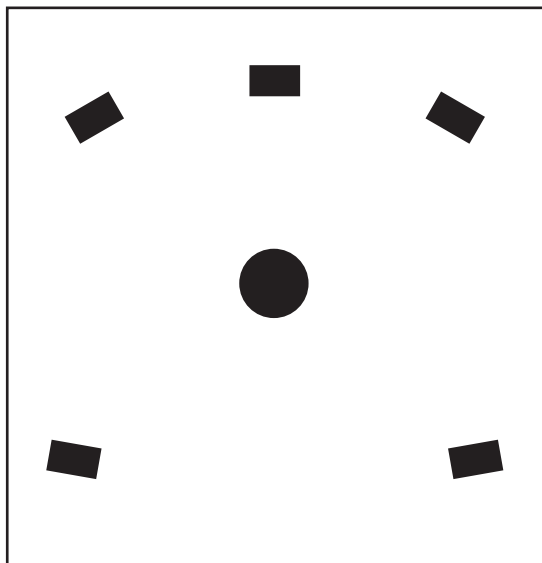


Figure 8a: The 5.1 setup. The front speakers are configured to a ± 30 degree angle and the rears at a ± 10 degree angle. The center channel rests at 0 degrees and is typically reserved for dialog, while the other channels are used for music and sound effects for realistic localization of the foley sound

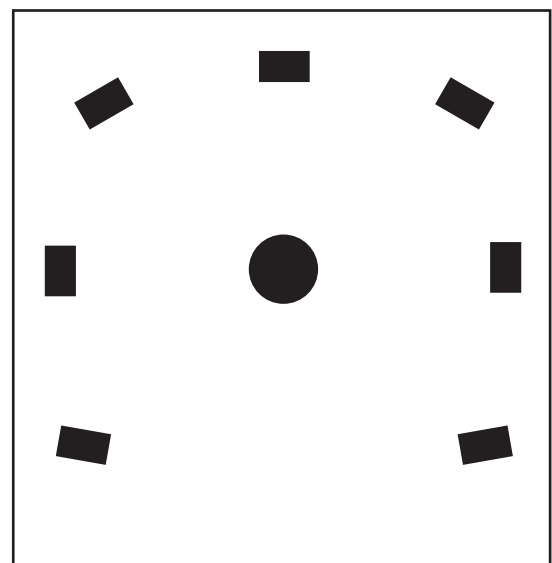


Figure 8b: The 7.1 system. This is the same as the 5.1 but with an added pair of speakers on the sides to fill out of the surrounding image for the audience. Again, the center channel is reserved for the dialog and the surround speakers are utilized to create more realistic surround sound and immersive sonic imaging.