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SPATIALIZED SOUND CREATION OF HERVÉ DEJARDIN: ELECTROACOUSTIC WORKS TO OBJECT-BASED BROADCASTING*

Günsel Işık GRUSON**
Taylan ÖZDEMİR***

Abstract
This article aims to shed light on the question 'How has the spatialized sound creation evolved from 5.1 and binaural production to object-based audio broadcasting?' by examining the career path of Hervé Dejardin, the project manager of Radio France's (RF) Innovation Department. The chronological thread consists of (1) Dejardin's early carrier; (2) organized sound spatialization approaches in his electroacoustic works; (3) binaural (3D) and multi-channel (5.1) audio broadcasting on web radio; (4) object-based live concert mixing and broadcasting; (5) post confinement projects and (6) Conclusion. Beside technical and project reports reviewed, Dejardin's transparent attitude in four interviews with him played a significant role in the preparation phase. The adaptation of his seven 5.1 works' channel bounces to the Dolby Atmos system in MİAM studios of Istanbul Technical University by Assoc. Prof. Dr. Taylan Özdemir made it possible to analyze them. Due to limitations, Ambisonics use in broadcasting and Dejardin's VR projects are excluded.

Keywords: Sound Spatialization, Binaural and 5.1 Broadcasting, Web Radio, Object-based Live Concert, Radio France.

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** PhD Candidate at Istanbul Technical University's Graduate School, Music Department, gunyilmaz@itu.edu.tr; https://orcid.org/0009-0005-0551-702X
*** Assoc. Prof. Dr., Faculty Member at Istanbul Technical University's Graduate School, Music Department, ozdemirtaylan@itu.edu.tr; https://orcid.org/0000-0001-8789-8893

Hervé Dejardin'ın Mekânsallaştırılmış Ses Yaratımı: 5.1 Elektroakustik Eserlerden Nesne Tabanlı Yayıncılığa

Özet

Bu makale, Radio France'ın (RF) Ses İnovasyon Bölümü'nde proje yöneticisi olan Hervé Dejardin'ın kariyerini mercek altına alarak 'Mekânsallaştırılmış ses yaratımı, 5.1 ve binaural prodüksiyondan nesne tabanlı ses yayıncılığına nasıl evrildi?' sorusuna ışık tutmayı amaçlamaktadır. Kronolojik konu akışı içerisinde (1) Dejardin'ın erken dönem kariyeri, (2) elektroakustik eserlerindeki organize ses mekânsallaştırma yaklaşımları (2004-2011), (3) web radyosunda binaural (3D) ve çok kanallı (5.1) ses yayını, (4) nesne tabanlı canlı konser miksajı ve yayını, (5) karantina sonrası projeleri ve (6) Sonuç bölümleri yer almaktadır. Teknik ve proje raporlarının yanı sıra Dejardin'ın kendisiyle yapılan dört röportajda sergilediği şeffaf tutum, makalenin hazırlık aşamasına katkı sağlamıştır. Dejardin'ın yedi adet 5.1 eserine ait ses kanallarının Doç. Dr. Taylan Özdemir tarafından İstanbul Teknik Üniversitesi, MİAM stüdyolarında Dolby Atmos sistemine uyarlanması, organize ses mekânsallaştırmasını analiz etmeyi mümkün kılmıştır. Çalışmanın kendi sınırları içerisinde, web radyosunda çok kanallı Ambisonik yayın ve Dejardin'ın VR projeleri kapsam dışında tutulmuştur.

Anahtar Kelimeler: Sesin Mekânsallaştırılması, Binaural ve 5.1 Yayıncılık, İnternet Radyosu, Nesne Tabanlı Canlı Konser, Radio France.

Introduction: Early Carier

A specialist in broadcasting and communication, Dejardin's career path is reminiscent of Pierre Schaeffer, a researcher-technician-composer who worked at RDF (Radiodiffusion Française) for radio drama productions in the 1940s, was involved in the invention of sound manipulation machines, founded the Studio d'Essai and began composing *musique concrète*: "It demanded musicians to abandon a priori thinking completely and return to experimenting therefore I became a musician at the end" (Schaeffer, 2012, p. 185). Born in 1962, Hervé Dejardin lived in Amiens, a major industrial area in the 1970s and 1980s where many professionals and students could gain experience. In high school, he received the French diploma 'Le Brevet d'études professionnelles' (BEP) in electromechanics: "This is how I learned about electricity, how electrical motors work, what can be done in big industries that make waves and so on" Dejardin explains in one of four interviews conducted for this article (2024-2025) and adds: "It helped me a lot to think in terms of sound; another eyes, another point of view about what I do today". He describes it as a "strange way of sound engineering" as he is very sensitive to electricity: when he mixes

with big sound systems he can say, "yes, we have a problem here because maybe we do not have enough energy (amps etc.)."

A multi-task professional in multimedia, he began his career at the age of sixteen as a radio technician and DJ presenter at an independent private local radio station in Amian. In the late 1980s, he went to London and worked for four years with a French DJ who developed various famous parties in Europe, including Paris, Nice and London. ("Especially at Cafe du Paris and Lime Line in London" adds Dejardin.) Here he met and played with different people like Boy George and David Bowie, and "learned a lot that required the responsibility of knowing people's reactions when they were lazy or ready to dance; how to keep people on the dance floor all night", but he wanted to add more to his path.

Dejardin defines himself as "a self-educated, lucky man who had a lot of chance" and says he learned sound engineering (in terms of programing and mixing music) from books. In 1992-93, he decided to set up a small home studio in Amian with a friend and produced commercials for a local branch of a private station, Nouvelle Radio Jeune (NRJ) which he became later a manager at one of its stations. The music program they used, Cubase, was designed for MIDI-only purposes: "No audio inside the computer, it was the start; it was not working yet, only three or four tracks" Dejardin explains but he states that despite the technical challenges, he loved it a lot.[1] For two years, he produced various productions -primarily electronic music- and composed electroacoustic music, but only in Stereo at that time.

Sound Spatialization Approaches in Electroacoustic Works

In 2005, seeing an open call for the annual festival of l'Institut de Musique Electroacoustique de Bourges (IMEB), Dejardin submitted *EvaluSon* (2004); the following year, he sent *Eau de vie* (2006) to the same event that let him earn the invitation. While working on *RER* (Réseau Express Régional) as part of his 2007 residency program at Studio Circe -which was going to be his last Stereo composition- the facility's assistant compared it to that of Åke Parmerud; he listened to the Swedish composer's *La vie mécanique*[2] (2004) in 5.1 format that he describes as "the work that gave me the light". "That is where we must go in terms of music and emotion. Writing music in space" he thought. Parmerud became a good friend of Dejardin and inspired him to compose music

for different festivals in 5.1 format such as *LocoJazz* (2008), *Révolutione* (2008), *The Bolduc Sound* (2009), *Variance Electrique* (2009), *Moyen Age* (2010), *Les Ballon* (2010) and *OSCI* (2011). In these etude-wise early multichannel compositions (Déjardin, n.d.), Dejardin developed a deeper perspective on the nature and spatialization of sound (organizing the physical [localization, motion and room acoustics] and perceptual [psychoacoustics] properties of sound in the sound space).

> **HD:** First of all, what is important in immersive production is the perception of sound. When you are producing sound, music and so on with the spatialization that means you design the universe in 3D, *at* 360°. It is to keep in mind what is happening in the nature… When you walk on the street, when you walk front of the sea, when you walk in the forest, when you walk everywhere in the nature, like you walk every day. All the time you have sound that moves around you. And some sounds attract themselves. Attract intention or not. For example, when you walk in the forest, between the trees, you have many of, many of, many of birds; many of movements of the trees, movements of the winds and so on, and so on, and so on. And that give you the symphony of the natural sound.

In *The Bolduc Sound*, between 00:59-01:10, an isolated, static sound object at the left surround reminds a barking dog however this sound repeats and familiarization shifts the reference from dog to a rhythmic pattern, therefore as a 'deformation of meaning', it becomes part of the spatial design. Dejardin comments on the auditory perception of invisible sound as follows:

> **HD:** All the time your brain tries to find you a reference in what you know in the natural world. What you saw during your life. It is logic. You have to know because your natural way of perceiving the sound is for protecting yourself. It is protecting yourself because this is the relationship between your subconscious to your conscious. And your subconscious is like a radar, all the time it protects you by perceiving sounds -and smells-. Sound -and smell-, this is the first sensitivity that gives you the perception of 360°. And after that, when you have the sound that gives you the perception of the danger, when you perceive a sound behind you for example, you turn your head, you put your head to your view and you decide if it is dangerous or not, if you have to run or not. And your brain, yourself, your culture was made with that. You built yourself in this environment. And you move yourself between these different waves, this complexity of the waves that give you the natural.

Dejardin cites the inspiration for his compositional expertise as Schaeffer, Karlheinz Stockhausen and Pierre Boulez, who contributed to the development of sound spatialization techniques and tools through their electroacoustic[3], electronic and computer music works composed for the virtual sound space. In brief, the Schaefferean way of creation considered the sound space through the exploration of grain, matter, morphology, energy and movement rather than harmony, melody or rhythm. (Anderson, 2012, p. 15). He also tried to 'manually control' the sound motion by using tools such as *potentiomètre d'espace*. Stockhausen, who as Dejardin quotes 'predicted that spatial

composition would be as important as vertical and horizontal in music, that is, melody and harmony' (FLUX::, 2019), sought ways to 'reproduce the spatial properties of sound' including direction, distance, and the Doppler effect: In his four-channel fixed-media work, *Gesang der jünglinge* (1955-56), he achieved a pointillistic, dynamic sensation by serially arranging static electronic sounds in different spots, while contrarily moving a recorded boy's voice back and forth very slowly to avoid coloration caused by fast sounds. In *Kontakté* (1958), he tried to achieve the Doppler effect manually by recording rotating speakers with four microphones and playing them back through a quadraphonic reproduction system (4.0). In 1960es and 1970es, the research on psychoacoustics[4], concert hall acoustics[5] and reverb units[6] became convenient resources for synthesizing spatial properties of sound (localization, distance, the Doppler effect) with computers[7]. In *Répons* (1981-84), Boulez used the 4X system of IRCAM as a real-time digital signal processor (DSP) beside orchestra, six soloists and dynamic electronics on the fixed media: During the concert, the solo instruments were captured live and their arpeggios with trajectories were played back from six loudspeakers around the audience, allowing static acoustic instruments to be 'spatially organized and moved' like pre-mixed electronics.[8]

Hervé Dejardin expresses that "for me, the art of spatialization is composing, designing, placing different sounds; the relationship between them makes the space, makes the movement. Like a symphony, like you mix the violins, cello and the double bass and so on. For me, this is the new orchestra": (1) In terms of 'sound material', his works consist of recorded natural phenomenon that carry the spatial sound conditions (*e.g.*, wind, rain, traffic, flights, crowd, birds) and isolated identical sounds with different morphological, typological aspects that aloud different gestures in the virtual space (*e.g.*, trains, scissors, balloons).

> **HD:** I have the Schaeffer culture of the sound material: It means for me, I have concentrated myself to perceive what I listen and I perceive the morphology of the sound. For me, mentally it designs a personality of the sound. Maybe it is a comic sound, it is a sad sound. Maybe it is a very animate sound, very slow sound like an elephant for example.
> **GIG:** What you are saying is very interesting in terms of your works from 2004 till 2011. We can hear the sources a bit like Trevor Wishart's... You use the water sound as a source and deform it as in Bernard Parmigiani's *De Natura*.
> **HD:** Yes, because first for me, what is important today is developing the capability to use natural materials, because I have tried to first perceive the natural music that you have in the sound and to play with it. And I use the material like an artisan works with a piece of wood or a piece of iron. You can do what exactly you want because this is the relationship between what you are trying to do and what the material authorizes you in terms of

> deformation and on the shaping the wave. That is why for me, what is really important in the work of Pierre Schaeffer -in terms of philosophy- is that he says, 'now, we can record a sound, we can stop it, we can play it at a different speed…' and playing it in the backwards and so on and so on. [*E.g.*, *Etude aux Chemin de Fer* and *Etude de Bruit* in 1948] What we can do today with the sound, at this point? Now, we can say 'it is not only energy, it is not only a wave, now it is a material' like a piece of wood, a piece of iron, a piece of what you want. First, once you understand that, you have the capability to start working with that but do not forget, the material imposes you to its shape.

(2) In his 5.1 works, 'sound scene separation' is employed between the frontal, central and immersive sound scene: For instance, in *LocoJazz*, the motion of the train is heard from the frontals and the 'breathing' of the railway is heard from the immersive sound scene. Using sound sources with different typologies prevents them from masking each other.

(3) In terms of 'structure', Stockhausen's Moment Form -that is a sequential arrangement of sections that constitutes a meaningful unit independent from each other- is absent in Dejardin's short works. *Revoluson* or *Variations Electriques* consist of different sections but they function in the narration. Also compared to longer works such as those by Vande Gorne, structural elements like contrast and continuity that enhance drama, or the use of spatialized sound key to separate sections and evoke expression through repetition are not essential to his creativity neither. As a signature, Dejardin sequences sound materials in various morphologies at different, fixed spots -in which sounds like pointillistic but not in 'space row' usage of serialist music or not randomized by a delayed pan- and develops them within repetitions beside other compositional tools. For instance, while small rhythmic patterns spread in the sound space, a 'dynamic sound transformation' accompanies them as a foreground sound activity. This practice can be titled as 'spatialized rhythmic pattern' (and 'spatialized music motive') that can be explained in other words as 'constructing a meaningful collage unit from different sound objects that spread to a larger sound scene from different zones'. This idea is notable as a signature used not only in Dejardin's multi-channel works[9] but also in his early Stereo format electroacoustic compositions. (*E.g.*, *EvaluSon* in 2004.)

(4) Dejardin makes advanced use of 'organized sound spatialization techniques' by incorporating 'narration'[10], 'symbolism' and 'synesthesia'[11]. He mimics physical elements of sounds that are in the memory pool of the gesture repertoire: For example the motion of seagulls is represented by the trajectory, the distance effect and the height effect (*e.g.*, high-pitched, narrow-band sound); the sliding door is represented by its attenuation

variances and dynamic panning; the motion of the wind is represented with pre-delayed whistles and the Doppler effect (pitch and volume variations); the crowd sound is represented by immersion; mechanical motion of train wheels going back and forth is represented by dynamic panning, close-distance relation and a repetitive rhythmic pattern that designed in different fixed spots. In *The Bolduc Sound*, Dejardin's style to carry the aurally referential (recognizable) sound objects into the virtual sound space within their spatialized symbolic relations also embodies the idea of synesthesia where isolated, short, sharp sounds of scissors are multilayered with rapid trajectories and heard as if they were cutting through the virtual sound space.

(5) 'Dynamic sound transformation'[12] in which sequential sound objects are manipulated and panned while maintaining a continues timbre is matured in his late compositions like *Moyen Age* and *OSCI* by using GRM Tools[13].

> **HD:** I explained my relationship with the sound material. Like an artisan with a piece of wood or a piece of iron. And after that, for me the best way to spatialize is without using panoramic [panning]. The panoramic tool is used to make a movement of one sound. I use it a lot, but for me, the best is when we do not use the panoramic. I want to design a universe with many sounds that play together and they do not move. But there is hundreds and hundreds of sounds everywhere that play, that change and I can move may be a bird of synth inside this.

Meanwhile, in 2009, in addition to his composition and production projects, Dejardin began Diplome D'Etudes Musicales (DEM) where he studied electroacoustic composition with Christine Groult at Pantin Conservatory for four years.

Exploring New Ways of Broadcasting in Radio France

Dejardin's career at Radio France began in Amian, where he occasionally worked in local studios, then moved on to a permanent position as a recording engineer at one of its stations, France Blue. In 2009, he renewed his position to work at the radio's headquarters in Paris: Leading sound engineer Antoine Lehembre, who had worked with many artists for RF Antenna's broadcast productions (*e.g.*, Peter Gabriel, Cure, Placebo) knew that Dejardin was working on a 5.1 system and to stage a multi-channel concert at the Radio, he invited him to the project: "I came to the studio with ProTools and plug-ins. Lehembre sent the multi-channel stems from the mixer and I moved the sounds in the box" narrates Dejardin. One year later, in 2010, he was mixing live at major festivals.

After the involvement in the Production Department, Dejardin set up his 'Immersive Studio' at RF. His recording of Fred Wesley's Vienna concert in 2011 with eight

microphones to capture the stage and the atmosphere around the audience was mixed by a colleague, Pascal Benard in a 5.1 system. Joel Gomez, who previously developed ARTE's website and was appointed as the Director of Digital Department at RF, liked the 5.1 mix he heard at the Studio. Dejardin explained that the best thing for radio was 'sound' therefore they had to renew and innovate it. When Lehembre left his position as sound engineer to become the second producer, he told Dejardin that he wanted the Radio to innovate in spatial and immersive audio, and offered his participation. Following these initial steps, the 'Innovation Department' of RF was established by Dejardin and his colleague Frédérick Changenet, under Lehembre's direction:

> **HD:** We decided to explore what is the new way for the broadcast in music and other content that radio produce; it means drama, documentaries, report and so on; and what it makes sense about the production in terms of spatialization for this in front way of production. It was the gool and the topic and we worked with Frédérick about that. We started to work and trained on that in 2010, 2011.

While researching new broadcasting methods, Dejardin met with Olivier Warusfel, the head of Acoustic and Cognitive Spaces Department of Institute for Research and Coordination in Acoustics/Music (IRCAM; *L'Institut de recherche et coordination acoustique/musique*); they discussed binaural technology, which was used in the industry but had not been evaluated for broadcasting cultural content yet. During these meetings, held between 2011 and 2012, they concluded that the Institute was ready to optimize the binaural rendering for web radio. Soon after, the BiLi (Binaural Listening) Research Project was established with collaborators such that Radio France, SDSM National Conservatory of Music, IRCAM, France TV and France Telecom (formerly Orange), which ran from January 1, 2013 to June 30, 2016. As part of the development of binaural renderer for 3D web radio, a digital distribution of different HRTF-i was provided for various ear morphologies, which users could download from the radio application on the web page. To improve the quality of the received sound as well as the production techniques, binaural coding methods were compared by Dejardin's team from Innovation Department through Dummy Head, XY and HOA recording tests. In March 2013, RF launched 3D (binaural) web radio NouvOson as one of the first attempts[14] to broadcast spatial audio productions to a wide range of audience by offering surround (5.1) and HRTF-i based binaural listening modes.[15] Since Gomez (from Digital Department) was specialized in documentary production, they first focused on this radio content; thus,

during November 2013, electronic music artist Molecule (Romain Delahaye) did the location recordings in the North Atlantic and Dejardin's immersive mix is streamed.[16]

While working on binaural and surround production and broadcasting strategies, Dejardin had an internship in 3D audio production at the National Audiovisual Institute (The INA*; L'Institut national de l'audiovisuel)* in December 2013. In here, he trained on the modular French music software 'Usine Hollyhock[6]' (Usine HH6; BrainModular, n.d.) which let him step into the hybrid, object-based audio workflow and allowed him to develop his own 'patch' (task planning by connecting different units in a modular music system) to use in his future small productions.

Meanwhile, after 3D audio streaming of live concert held at the Champ de Mars in July 2014 that organized by France Music (channel 3 service of Radio France) and Culturebox (France TV), a new on-demand web service, 'Hyper Radio' was established to broadcast post-production works in a large variety such as studio recordings, fixed media works, live concert recordings of festival programs and solo performances; all in binaural and 5.1 formats. Besides having documentary and fiction categories, by including a variety of genres such as electronic, mix, acoustic and electroacoustic music (that also consist of works by renowned composers such as Pierre Henry, Jonathan Harvey and Åke Parmerud), it has offered a cultural, educational and archival service for immersive creation within diverse production and aesthetic approaches (Radio France, n.d.). In February 2015, Dejardin wrote the technical aspects of a 3D web radio player in his AES paper, *NouvOson Website: How a public radio broadcaster makes immersive audio accessible to the general public?* where he summarized the outcome as below:

> The gap between 5.1 and the ability to manage many virtual sources in binaural as well as the need for more virtual channels than the classical 5.1 have led us to object-oriented mixing and new ways of producing audio. The WebAudio API will be a good tool to manage all these future applications (Dejardin, 2015).

In the context of a new radio production project, Dejardin contacted Matthieu Parmentier from France TV's Innovation Department to evaluate the use of binaural listening mode (and technology) for culturally relevant music recorded or mixed in 3D. Thus, a documentary project featuring immersive binaural audio and 2D video, 'Sequences: Electronic Live Sessions', premiered on April 16, 2015 with contributions of France TV's Culturebox and co-production of Dejardin and NouvOson from Radio France. From a

production perspective, each episode featured cameras rotating 360° around the electronic music artists, recording them in synchronization. Next, Dejardin mixed and made spatial design of multi-track recordings of these live studio performances in 5.1 and binaural audio with his Usine HH6 patch to render the movements in the virtual sound space. The general idea was to show the audience what was being done with synthesizers, drums, etc. during the interpretation but Dejardin notes that in the post-production, the director and editor were listening the immersive binaural mixes with him to produce a 2D image therefore "the main purpose was to see how the binaural listening mode in editing of the images affected the video production." This project remained open to the public with the contribution of Dejardin as he discussed the issue with Xavier Gibert from Radio France International (RFI) (France Télévisions, n.d.). One month after the launch of Sequences, Roland Garros broadcasted in binaural mode (24 May-7 June 2015).

The file sharing problem caused by the variety of formats, interfaces, hardware and software in hybrid systems had been the subject of research in many institutes and tried to be solved by sort of standardization attempts. (*E.g.*, Spatial Sound Description Interchange Format [SpatDIF] for sound storing between different programs such as Max MSP, Pure Data [Peters et al, 2013]; MusicXML open format for sharing music notation between different software.) In 2015, the overarching interchange format, Audio Definition Model (ADM) was conceived by the EBU which followed by the announcement of MPEG-H by The Fraunhofer Institute. At the end of the year, an international research program on the object-based broadcasting, archiving and streaming was acknowledged under the name of The Orpheus Project[17] (December 1, 2015 and May 31, 2018) with the participation of organizations including RF (immersive web), the EBU (ADM), IRCAM (personalization of programs and object-based Reverb IR algorithm used with ADM) and the BBC (interactive audio-video streaming) (*ORPHEUS - Object- based Audio Experience*, n.d.). The outcome of the project was exemplified as an on-demand drama production with metaverse visuals and binaural listening that streamed by the BBC on HTML5 based browser: the personalization was provided by audio objects and metadata that were adjusted in the menu (*e.g.*, language, dialogue volume) (Baume, 2017).

Object-based Live Concerts with Electronic Music Artists

Dejardin was using Wave Field Synthesis (WFS) as the spatial renderer that designed by Etien Cornell from Sonic Emotion since 2014 ("the company does not exist today"); in

early 2016, he revamped 'a 3D sound lab' in his Immersive Studio with the monitoring system consisted of four layers and two large subwoofers: sixteen loudspeakers in ring one, eight loudspeakers in ring two, four loudspeakers in ring three and a 'voice of God'. WFS system was giving the opportunity to virtualize the sound behind the loudspeaker but not in front of them however Dejardin had a speaker agnostic system with LoopBack virtual sound card, Nuendo and Usine HH6 therefore he could simulate sound both behind and inside loudspeakers. He could also switch between different reproduction systems such as STR or 5.1 and virtualize for different final addresses and formats. "They send the design of the loudspeakers; I virtualize it in WFS and mix for them" he explains.[18]

After his three years of expertise on Usine HH6, his role in the Orpheus Project and renewed 3D system of the Studio, the Music Department of RF approached Dejardin about staging a few small concerts with the 'object-based audio' in the circular central area of the Radio and requested a technical rider to learn how many loudspeakers would be needed for a multi-channel live mix. Dejardin demonstrated a system with his Usine patch that he was developed for Sequences; he refined it further within a month and used it for immersive concerts at RF, where he 'performed' the multi-channel live operation of 'electronic music' with artists such as Molecule and Chloé. The genre-specific choice of Dejardin incorporated a framework about sound spatialization that differed from his electroacoustic works:

> **HD:** From my side, I worked particularly -and concentrate myself- about music. Especially electronic music. Why? Because I love electronic music of course but more than that, for me it was the best way to develop spatialization for music. Why? Because first, electronic music composers are young. They are very fresh; they have a lot of energy; they have a lot of curiosity and they want to try a lot of different things. But as well, in electronic music, you do not have any cultural references. To explain what I mean by that, if you want to spatialize for example a violin, you have to compare the sound you hear with your reference, which is the natural way of listening. When you listen to a violin, you listen of course a melody. A melody inside the composition and you see mentally the musician and the way he plays the melody. That is not the case with electronic sounds, because electronic sounds are absolutely without reference. And that is why for me it was very interesting to explore this way because synthesis or sampling sound have not got references and you can play with them like you want.

Following Molecule's concert at RF on May 17, 2017, Dejardin was asked by the artist's promoter a collaborative work at the Rex Club in Paris. He then met with Guillaume Le Nost, Research Director at the L-Acoustic Laboratory (L-ISA System) in London, to request sponsorship and a sound system "to have a big experience". In return, Dejardin

received an offer for an immersive live tour and the assurance from the company including the concert at the Rex Club. They signed 'Acousmatic 360°' live tour as Dejardin agreed to take part in the project with Molecule not as an individual but as the sound spatialization engineer, representing the corporate sponsorship of RF. It was known that he was working on Usine HH6 so L-Acoustic requested the workflow to be completely in 'object mode', offering their own system which also included remote control software. Over the summer, Dejardin focused on developing his work chain for live sound operation, including Usine, SPAT Revolution, Nuendo, L-Acoustic's L-ISA loudspeakers and a beta version of L-ISA control software that he modified. Finally in September, the system worked and on October 18, 2018, they gave their first 'concert in the dark'[19] at the Rex Club, where Dejardin performed live sound spatialization alongside Molecule in the center and the audience surrounded them by placing inside the 360° (in 2D) speaker array.[20] It was followed by a second performance at Printemps de Bourges on April 18, 2019.

Dejardin admits that his live concerts are a continuation of his research work, "experimenting with workflows, audience reactions, different venues and so on". In the concept of the 'concert in the dark', it can be assumed that the listening activity, and therefore the perception of the sound spatialization, is more focused in the ongoing Acousmatic 360° concerts. Another specific example is Dejardin's collaboration concert with Maud Geffray and Laure Brisa that took place at the semi-anechoic (half-isolated) Centre de Transfert de Technologie du Mans (CTTM), on January 27 and 28, 2022. The venue was an antique sound volume measuring laboratory for industrial sources used by acousticians therefore without having the reflections of sound walls, this concert may have provided the opportunity of controlling the virtual space parameters and reverberation in a new dimension (*Maud Geffray - Still Life - Concert en son 3D*, n.d.).

In 2019, Dejardin's R&D team at RF along with L-Acoustics and FLUX :: Immersive, who collaborated on the Acousmatic 360° project with him, announced the ADM Open Sound Control (OSC) protocol that allowed metadata exchange between different equipment in a 'fully object-based system'. By using multi-channel and binaural rendering simultaneously, 'on-demand only' 3D web radio streaming was up-graded as 'live'. That way, Dejardin's concert series started to be live streamed by RF under the name of FIP 360, including the Acousmatic 360° concert on October 18, 2019 that took place at La

Cigale (Paris) with video shooting of Culturebox from France TV. In object-based audio production, all automated and programmed sound spatialization parameters of the mix are archived as Cartesian coordinated metadata, representing the events of audio objects; all of which can be later edited and rendered in other software such as SPAT Revolution.

Post-Confinement Projects

At the beginning of the confinement in 2020, Hervé Dejardin was working on the amelioration of movement generator in Usine HH6 by working beside L-ISA processor and the SPAT Révolution software to apply them in FIP 360 live shows and the Acousmatic 360° tour. Same period, a team at RF[21] including Dejardin developed a non-stop 3D audio streaming strategy for Vincent-Raphaël Carinola's online work, *Flux Æterna* (2014), which programmed to generate and spatialize itself without any pause by exploring automation, probability and variability of numerical coding beyond digital processing such as 'fragmentation, transposition, compression, filtering, modulation'. The work, ran on air between February 2020 to February 2022 on France Music, offered binaural listening and allowed audiences to integrate with pre-programmed structure through importing their own audio files to the web page. (*Flux æterna - Vincent-Raphaël Carinola*, 2024)

At the end of 2020, after the coordination of the Director of the Music Program of RF, Dejardin is participated in a post-production project to mix immersive sound for Jean-Michel Jarre's New Year concert 'Welcome to the Other Side' given in the virtualized version of Notre Dame de Paris[22]. Jarre was performed this concert in stereo, using tracks from previous albums; he sent multi-channel audio files in January 2021 and Dejardin's spatialized version of the concert is released in binaural and 5.1 formats on Hyper Radio on March 17, 2021 (Radio France, n.d.). This work was followed by two more collaborative projects with Jarre: *Amazonia* which was available only in binaural version on Hyper Radio and *Oxymore*[23] that released at the end of 2022. This album, featuring audio materials of Pierre Henry, was spatialized in the Immersive Studio at RF by Dejardin with Nuendo, SPAT Revolution, Usine HH6 and L-ISA monitoring system. On January 14, 2023, it is launched in a concert with having Hervé Dejardin on the control desc of virtual space at IRCAM where room acoustics were synthesized and number of sound motion tools were developed in its labs since mid 1980s. The French Minister of

Culture was also invited, highlighting the significance of this event as a milestone symbolizing the maturity of sound spatialization studies and technologies.

> **GIG:** When I listen to your music, I hear the mechanics, the wheel of the clock. We are in a machine when we listen your works. This is exactly what I hear in *Oxymore* which makes this album even more interesting: the organization of sound spatialization. I think this is one of the reasons why *Oxymore* is different than other albums of Jean-Michel Jarre and I would like to talk about it because this is where we connect your creation in your electroacoustic compositions with electronic music mix.
> **HD:** The reason you perceive my composition for example on 'Epica' -the last track of *Oxymore*- is that you have a very discrete but very nice, a small rhythmic pattern that I designed. It is the composition of Jean-Michel, but I spatialized the rhythmic. I said to Jean-Michel, "look, when I isolate just that rhythmic, we can perceive a lot of sound" and he was very cool. He said "yes, it is very nice, I will modify the orchestration." And this is the way I love to spatialize, that to put different sounds with relationship in the time and spectrum and to have the movement between them.
> **GIG:** Yes, because here sound spatialization is in a different approach while it means localization, movement, Doppler effect and reverberation for many others.
> **HD:** But you know why? I was inspired of the work of Åke Parmerud on *La vie mécanique*. When I listen this rhythmic of Jean-Michel, I said "for me this is not a rhythmic, this is a machine. This is a mechanical system." And for me, that is it! And when I design the space, all the time, I have a representation in my imagination.

Since then, Dejardin has been contributed to the sound spatialization of number of music albums and singles that is not limited to electronic music which, in general, is open to creation with blank pages where rules or aesthetic choices do not exist and guidance might be required. Dejardin's approach to each project changes in a way that reminds his thoughts on the sound object that connects artists to their own nature. For instance, comparing to the wide spatialization palette of *Oxymore*, in Arthur H's 2024 album *La Vie*, spatialization is used in a more minimal way (as it would be expect from cabaret ballad style). In the first track of the same name, the immersion gives more space to musical elements with sound scene separation and spread in the virtual sound space (*e.g.*, electronic FXes). While strings are slightly dynamic panned, the hard compressed vocal is static therefore even though it is far away, its presence is evident as would be expected from a solo album, but it is localized in a balanced manner within the immersive virtual space. Reflecting on his last collaborative work with DeLaurantis (Cécile Léogé), Dejardin explains that sound spatialization is a continuous search for him as follows:

> **HD:** I love to have the music like a road and some even design the next, design the next… That is the relationship in terms of time, in rhythmic and of course in melody and so on that inspires me. For example today, I work with DeLaurantis, very good composer. When we decided to work together on the album and she started to wright and compose, I said "Cecile, we have to take a time to explore electroacoustic music and its relationship with sound material." We listened my work, we listened the work of Åke Parmerud and so on... And after that, it was very nice because she said to me "Hervé, I want to compose a piece with you, it will be the first track of my album". We bought a painting box and so on and

so on, we composed together by recording during two days, many sounds that we designed: some paints, some roller on different surfaces because the story of the album of Cécile is about the relationship between 'a musicalist' and a painter in France. (Last century, where painters listen to the music, they closed their eyes and they have this 'synesthesia' experience. People that have color or form in the brain when they listen to music. And this is the subject of her album.) Cécile in the studio and me in here [Immersive Studio at RF]. I reproduced 'this world of creation' that you perceive in my piece.
GIG: Yes exactly, this is the signature.
HD: The axis of my work is to go very, very deeper in this world because for me, the music that I have dream in my head, it's a big mosaic in terms of composition.
GIG: This is what I hear when I listen.
HD: What I try to do more than that today, like I use my expertise to help composers like Jean-Michel Jarre, Cécile 'DeLaurantis' and so on; in these projects, I rebuild the sensation of the perception of the nature. But this is not the nature, this is absolutely a synthetic universe.

Conclusion

By featuring details on his creative projects, this article revealed how Dejardin built his expertise on sound spatialization and contributed to object-based audio broadcasting. In addition, excerpts from interviews conveyed his conceptual thoughts on 'electroacoustic music, electronic music and immersive audio', which he cited as his sources of inspiration. In the second section of the article, it was observed that Dejardin established his organized sound spatialization methods such as 'spatialized rhythmic pattern', 'dynamic sound transformation' and 'spatialized symbolism and synesthesia' as some of his creative signatures in his electroacoustic works between 2004-2011. In the third section, as the representative of RF, Dejardin's collaborations with the R&D departments of international institutes and organizations -such as the BBC, EBU, IRCAM and L-Acoustics- to develop strategies for broadcasting spatialized sound were exhibited. In addition, some of the projects (Bili Project, NouvOson, Hyper Radio, The Orpheus Project), formats (ADM OSC), tools (L-ISA controller software) and technology (WFS rendering processor) in which he was involved or played a role in their development were introduced. The fourth section clarified that in his concert mixes that broadcasted live on FIP 360, Dejardin used 'object-based only' workflow (*e.g.*, L-ISA processor, SPAT Revolution, ADM OSC transmission protocol and Usine HH6 patch for programming sounds in motion), which aloud simultaneous binaural streaming and archiving of live mix operations by saving sound objects' cartesian coordination as metadata that could be transmitted, played in another system or post-mixed. Beyond these technical aspects, it was demonstrated that as part of Dejardin's ongoing research approach, his concerts such as

the one in the dark or in a semi-anechoic hall became a sound laboratory to explore the relationship of sound in acoustic and virtual space. Observations suggest that due to his expertise on the operation with updated software, hardware, formats, and background of thirty-five years DJing and electronic music production, he has become a 'performative sound engineer' for object-based live concert mixing (*e.g.*, Acousmatic 360° and FIP 360), which corresponds to Vande Gorne's expression of mastering live sound spatialization at a 'virtuoso' level. (Gorne, 2002). In the fifth section, the influence of his early electroacoustic works on contemporary collaborations is identified in terms of organization of rhythmic sessions, spatial symbolism and synesthesia. Consequently, Hérve Déjardin adapts the approaches to sound spatialization developed since the 1950s through electroacoustic, electronic and computer music to the present day; combining technique with creativity and clarity, elevating it to universal value. His enlightening tendency to ensure the accessibility of theoretical and practical knowledge and his efforts to bring cultural radio content to all audiences place him as an inspiring exemplary figure beyond his expertise in spatialized sound creation and broadcasting.

> **HD:** You have to think to keep in mind that this system, the transmission of the sound today gives the capability to share the new experience to perception, of emotion, of writing music and so on. It is a new field of experience to share. And this field is very large, may be infinite. For me, the only limitation is our imagination. That is it.

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Notlar

[1] At that time, they had Akai S1000 MIDI stereo digital sampler, Yamaha RM50 drum box and Yamaha DX7 IID synthesizer in the studio.

[2] Dejardin also calls Parmerud's *Crystal Counterpoint* (2009) as another inspirational source.

[3] Some of Dejardin's sound objects can be considered references to this ecole: 'Train' sound in *LocoJazz*'s intro for referencing Pierre Schaeffer and his '*Étude aux Chemin de Fer*' ('Railway Study'); 'door creaking' sound in *Les Baloons* (02:06) and *Moyen Age* (02:27, 02:49) for referencing Pierre Henry's *Variations pour une porte et un soupir* ('Variations for a Door and a Sigh'; 1963); 'burning coil' sound for referencing Xenakis' *Concret PH* (1958) and *Analogique B* (1958-59; composed by stochastic, pre-granular synthesis).

[4] Max Mathew expressed that he produced 'horrible' sounds with his first music software, Music 1, in 1957 (Risset, 2015) however he continued to search for ways to synthesize a natural quality sound that heard similar to 'acoustic waves' (Mathews, 1963). Also even the physical sound signal and the effect of the acoustic space on it can be measured with tools ('Bayle's interview' in Pires, 2007), many researcher-musicians agreed that sounds that can be heard but cannot be measured, such as 'phantom sounds' (Schaeffer, 1966), should also be investigated. Thus, among the names whose works in the field of psychoacoustics and auditory mechanisms were cited to contribute to the research on sound spatialization were Hermann von Helmholtz (the organ of Corti, the azimuth-vertical localization, the distance factor, the priority effect, resonance theory -place theory-; in 1863), Lord Rayleigh (binaural auditory model, horizontal perception with duplex theory, head shadow; in 1876 and 1907), Robert S. Woodworth (binaural hearing, spherical hearing method at eye level; in 1938 and 1961), Georg von Békésy (function of the cochlea; in 1932-49), Harvey Fletcher (equal-loudness curve; in 1933), Hans Wallach (the precedence effect; in 1949) and Helmut Haas (the Haas effect; in 1949) (Lyon. 2017; Wenzel et al., 2018).

[5] In the early 1960s, 'acoustic architects' such as Leo Leroy Beranek and Hans Scharoun followed in the footsteps of Wallace Clement Sabine who applied science to acoustics by experimentally solving the masking effect of reverberation using absorption rates of materials at Harvard University's Fogg Lecture Hall in 1895. Beranek, whose field research in 1962 enabled him to evaluate the acoustics of the halls with the comments of well-known musicians (warm, clear etc.), built more than sixty concert halls. In the repair of circular Berlin Philharmonic Hall between 1961 and 1963 -which, like the Royal Albert Hall, was designed similar to the ancient theater modeled by Vitruvius-, Scharoun reduced the time it took for direct sound to reach the audience from 50 ms to the ideal, under 20 ms (Blesser and Salter, 2007).

[6] Vermeulen's analogue delay wheel to Schroeder's digital reverb unit: In the mid 20th century, while electronic devices were in the development stage, existed concert halls started to be equipped with multichannel loudspeakers. The creation through virtual sound space was a new concept and playing it by loudspeakers in isolated concert halls sounded dry. In the first half of the century, 'reverb chambers' -placing speakers in a room and bouncing the sound that washed by and reflected from walls- were used to create a sense of space for radio drama, film, and music productions but this practice was unsuitable for large halls (Blesser and Salter, 2007). To create a homogeneous diffusion through loudspeakers, Roelof Vermeulen from Philips Research Laboratories in Netherlands was developed his analogue delay wheel to use as a reverb effect in concert halls which was based on the principle of widening delayed sound, in other words, Haas Effect (Vermeulen, 1958). For accurate reproduction, he applied different delay times to signals with gradually decreasing sound levels on his multi-channel set-up. A few year later, a 'non-colored, digital reverberation' ('ambiophonic') was introduced by Bell Laboratories' researcher, Manfred Robert Schroeder in 1960. To diffuse a 3D reverberation that would spread with the reality in the virtual sound space, Schroeder wanted to bring different reverbs to the surround speakers therefore he used a combination of an all-pass filter, 4 comb filters and their short-delayed versions, feeding the loudspeakers with a 16 channel Matrix (Schroeder, 1962). He wanted to achieve a non-colored effect by using an all-pass filter that passed all frequencies with equal gain but while this process worked for static sounds, it would cause 'coloration' on fast-moving sounds, in other term 'variations in reverberation intensity across a large critical band that ends up with an unnatural listening condition' that would be corrected by Chowning a few years later.

[7] Researcher-composer John Chowning studied electroacoustic music in Paris in the late 1950es with no previous computer experience, and was 'fascinated by the idea of composing for loudspeakers' after hearing Stockhausen's *Gesande Der Junglinge* (1956). When he returned to the United States in 1963, he

collaborated with James Moorer at the Center for Computer Research in Music and Acoustics (CCRMA) at Standford University; and that same year, Princeton University acquired a copy of the source code for MUSIC IV, a music software program developed by Bell Labs (today's Center for Computer Research in the Arts [CRCA]). As a sample generator computer, MUSIC IV was converting numbers into sounds via operators, modulators, filters and noise generators (functioned as a 'synthesis orchestra') but in terms of sound's spatial aspects, it was limited to the 'azimuth dimension' and had only a delay unit for reverberation. Chowning developed a new version of the software using PDP-10 computer in collaboration with Moorer (therefore this version called MUSIC 10). He used Schroeder's reverb that has all-pass filter, comb-filter and delay; and also generated sound by using FM synthesis. Next, he digitally modeled distance, localization and motion in the computer: Distance was created by intensity variation using inverse square law separately for direct and reverberated sound...; Localization was achieved by differentiation based on IID and ITD in the horizontal plane; Moving object's Doppler effect was synthesized by variation in frequency (FM modulation), intensity (AM modulation) and reverberation -thus the 'coloration' of Schroder's reverb caused by fast sound motion is corrected-. Chowning demonstrated these sound spatialization methods in his computer music work, *Turenas* (1971-72) that gave the impression if generated sounds were rotating in the immersive sound scene of quadraphonic reproduction system. He also introduced a musical tool constructed of a cathode ray tube (CRT) and a moving arm that controlled localization, distance, the Doppler effect and motion that allowed the computer to memorize the parameter changes caused the drawing on the Cartesian plane (Chowning, 2011; Peters et al, 2011; Lazzarini, 2013).

[8] In the 1980s, Music 10 was used by IRCAM's '4X' computer system, capable of DSP, synthesizing, AD/DA conversion and scheduling (object connection) in real-time. The possibility of spatialization and automation with live processing offered new sound space considerations, which Boulez experimented in his *Répons*: In this work, a twenty-four piece orchestra sits in the middle of the stage; six soloists (a harp, a vibraphone, a cimbalom, a piano, 'a Yamaha DX 7 synthesizer and a piano', 'a glockenspiel and a xylophone') position around the audience**;** the sound produced by the solo instruments are captured by microphones, are modified (by localization, pitch, time etc.), programed (*e.g.*, speeding up with increased amplitude, automated trajectories) in real-time by the 4X and sequenced by Matrix 32 to be played through six loudspeakers surrounding the audience (*e.g.*, turning motion of unprocessed and processed short solo arpeggios heard one by one by loudspeakers). 'While antiphony of soloists and orchestra is heard, the digital reverberation of pre-mixed electronics envelope the audience' (Ircam, 2020).

[9] *E.g.*, In *Impression*, a meaningful spatialized rhythmic pattern is heard at 00:33-00:37 from L-R loudspeakers then spread to the immersive sound scene. Furthermore, a spatialized rhythmic pattern (00:44-01:34) is multilayered by a spatialized music motive that introduced between 00:43-00:50 that created a larger music scene in motion.

[10] Anecdotal music tells a story without separating sounds from their source, preserving their meaning about an event. *E.g.*, In Luc Ferrari's *Hétérozygote* (1964), dialogues and musical sounds are heard in the original field recordings.

[11] 'Synesthesia' is a neurological condition where a feeling is transformed into an unfamiliar emotional state. For instance, letters or numbers can be perceived through different sensations such as colors, tones.

[12] Examples of sound transformation can be found in Stockhausen's *Hymen* (1960-67); Milton Babbitt's *Philomel* (1964); Luc Ferrari's *Presque Rien No. 1* (1970); Parmigiani's *De Natura Sonogram* (1975); Westerkamp's *Cricket Voice* (1987) and Denis Smalley's *Empty Vessels* (1997) (Emmerson, 2013; Roads, 2015).

[13] Background of GRM Tools (a digital signal processing module): In 1940s, Schaeffer was working at Club d'essai de *Radiodiffusion-télévision française* (RTF) that turned to Groupe de Musique Concrete, Club d'Essai (1951) and Groupe de Recherches Musicales (GRM, 1958). GRM and Studio EMS developed a real-time, hybrid analogue-digital system, SYNTOM (Synthing TOM) in early 1970es. In 1975, the organization became a part of Institute National de l'Audiovisuel (INA) and beside having MUSIC V as software, it owned a powerful, PDP-11 computer. In 1985, GRM developed its 'real-time' computer music system, Systeme Temps Reel (SYTER) that included AD/DA converter and a Graphical User Interface (GUI) with a mouse as a controller. Soon after, the creative ideas became plug-ins such as GRM Tools (1990) and GRM Acousmograph (1991; visual audio analyzer) (Puckette, 2002; Möllenkamp, 2014).

[14] According to Périaux, other similar web radios of the period were Concertzender, Antenne Radio, Rock Antenne (2015, p. 16).

[15] A decade after the first 5.1. digital audio codecs -Dolby Digital (DD) in 1992 and DTS in 1993-, TVHD started to 5.1 broadcasting in 2004 (with DD); Blue-Ray, SACD and DVD-A were used as multi-channel fixed medias. Same period, Digital Audio Broadcasting (DAB+) started to replace analogue antennas. 5.1 audio files could be downloaded via streaming and played back by iTunes, QuickTime, VLC player and Windows Media Player but it was QuickTime HD which made 'live multi-channel audio streaming' possible. Currently, HD TV receives multichannel audio; with HDMI connection, house receivers play back HTML5 streaming (*Ibid.* p. 14-16).

[16] Molecule released his 5.1 album *60* 43' Nord* with Dejardin's mix in 2014.

[17] The Orpheus Project had two audio delivery options: (1) First one was the 'object-based for content delivery network (CDN)' that reduced the number of objects then applied ADM metadata and MPEG-H legacy coding. In terms of reception, a receiver or a user interface was required to decode ADM streaming (with ITU-R based renderer) and MPEG streaming (with C++ based renderer). For binaural listening mode on mobile devices, MPEG-H renderer with HRTF was used without the need for live rendering of objects. (This delivery also had to read channel-based audio as well.) (2) The second one was the channel-based audio delivery that was the downmix version of the object-based audio for broadcasting by antenna (DAB+) and satellite (DVB-S) which then received by a regular radio. (*Public Deliverables - ORPHEUS,* n.d.).

[18] For instance, Dejardin explains that using the same system, he recently produced binaural for ARTE VR and Ambisonics for Molecule to be reproduced at different domes such as the Society for Arts and Technology (SAT) in Montreal.

[19] The name of the duo project 'Acousmatic' and 'the dark concert' concepts are based on 'acousmatic music' that referred to the works played through loudspeakers with no visual guest of sound source. Schaeffer used this term to refer to Pythagoras, who is said to have taught from behind a curtain, to reinforce the meaning of his words. Schaeffer was maintaining this term from phenomenological aspect to define listening sounds for their sake, without thinking the referential sources by applying 'reduced listening'.

[20] In Acousmatic 360° concerts, eight L-ISA speakers' immersive design is reminiscent of (1) English composer Thomas Tallis's *Spem in Alium* (1573) composed for eight choirs of five soloists in each -40 in total- surrounding the hall and some works of American avant-garde composers written for eight magnetic tapes surrounding the audience, such as John Cage's *Williams Mix* (1952), Earle Brown's *Octet I* and *II* (1953-54) andf Morton Feldman's *Intersection for Mafnetic Tape* (1953).

[21] Also Frédéric Changenet, Pierre Charvet and Justine Mergnac-Herstenstein (Changenet et al. 2016).

[22] In '2020 Paris New Year concert', Jarre was performed in a green studio while his avatar was placed in the modelled version of Notre-Dame church (which was burnt on April 15, 2019), and the concert was live broadcasted in 'Stereo' format on Fip radio.

[23] In a 2024 mini survey conducted among students of the Sound Engineering and Design Program at Istanbul Technical University's Graduate Faculty, and students in the Music Technology Department at Istanbul Technical University's Turkish Music State Conservatory, one participant raised the following question: "In *Oxymore*'s Neon Lips, was dynamic panning synced the song's beat by using programmed panning?". When asked this question during interviews, Dejardin stated that in the whole album, he wrote each automation by hand in Nuendo.