Auditory Tactics: A sound installation in public space using beamforming technology

Philippe-Aubert Gauthier, Ph.D., M.Sc., Eng. Jr, sound artist
Philippe Pasquier, Ph.D., M.Sc., sound artist

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Philippe-Aubert Gauthier, Ph.D., M.Sc., Eng. Jr, sound artist
GAUS (Groupe d'Acoustique de l'Université de Sherbrooke), Université de Sherbrooke
CIRMMT (Centre for Interdisciplinary Research in Music, Media and Technology), McGill University
e-mail: philippe_aubert_gauthier@hotmail.com
web: http://pag-sound.blogspot.com

Philippe Pasquier, Ph.D., M.Sc., sound artist
SIAT (School of Interactive Art and Technology), Simon Fraser University
e-mail: pasquier@sfu.ca
web: http://www.sfu.ca/pasquier

Abstract

The term "auditory tactics" refers to the contextual listening attitudes and competencies adapted to various private and public auditory contexts, spheres and aural architectures. Auditory Tactics is a spatial sound installation designed to interfere and play with the auditory tactics of the passerby in a public space by projecting sounds from more private spheres. Created for the Pure-Data Convention 2007 in Montréal (Canada), the novelty of this work is the use of beamforming: a sound projection technology which allows the creation of directional sonic beams resulting in illumination and shadow zones that dynamically interact with architectural surfaces. We report the results and lessons of this first artistic experiment with sound beams as a creative sound-projection method.

1 Introduction

In previous decades, the development of affordable multichannel sound cards and computer-based digital audio generated an unprecedented availability of multichannel sound. Although artistic interest in natural or artificial spatial sound is not new [1], these recent developments have transformed artists' relationships with sound spatialization. Originally restricted by expense to work by world-renowned composers (Varèse, Stockhausen, Xenakis [2]), spatial sound is now common in sonic art and electroacoustic music as well as in popular media.

In 2006, we were invited [3] to produce a spatial sound installation in a public space in Montréal (Canada) for the Pure-Data Convention 2007 [4].

At the conceptual level, we were interested in the interplay between various auditory spheres and the concomitant auditory tactics. The term "auditory tactics" refers to the contextual listening attitudes and competencies adopted or developed to achieve specific auditory tasks when different acoustical environments or aural architectures are encountered. As we are currently witnessing an explosion of mobile technologies Walkman, MP3 players, mobile phones and noise cancellation earphones which by artificial means allow for sonic and spatial cohabitation of personal and public spheres, we decided to address this theme in our installation. Our idea was to attempt to interfere and play with the auditory tactics of the passerby in public space by projecting sounds associated with more private and intimate spheres. Auditory Tactics is also a novel exploration in beamforming for sound reproduction. This technology allows the creation of directional sonic beams with interesting reflective properties. The possibility to create illumination and shadow sonic-zones by remote means inspired us with respect to the aforementioned idea. Using a custom-built system, this is to the authors' knowledge, the first time this technology has been applied to a sound installation in a public space. This paper aims to present the results and lessons from this experience while balancing the social, artistic and technical dimensions of the project. We report and discuss both the conceptual and practical elements of the project throughout.

The first section of this paper introduces the artistic and technical background to this project along with our initial motivations. The second section describes the creation process, and the conclusion discusses the results and observations made from the installation.

2 Background and Motivations

2.1 Spatial sound

Any perceived sound is naturally spatial. Indeed, sound propagation in air is space-dependent as is human sonic perception. Given this naturally three-dimensional auditory experience, to what does the expression spatial sound refer in sonic art and acoustic engineering? It originates from a diachronic perspective on sound technologies, which in their infancy constricted the reproduced spatial auditory experience to a monophonic transmission line. It may be this major technological distortion of sonic space that suddenly revealed the aesthetic potential of spatial sound, suggesting novel possibilities beyond increased realism.

Since the beginning of the modern technological era, spatial sound has been explored and continuously redefined by artists in electroacoustic concerts, sound installations and performances with or without the help of technological developers. There would be as many motivations for and conceptions of spatial sound as there are artists. It is possible, however, to note a dominant feature: spatial sound typically involves the relative movement of the perceived sound and the audience. Auditory Tactics addresses these two dimensions.

We also endorse spatial-sound art as an avenue to move beyond spatial sound as a perceptually and aesthetically pleasurable presentation mode and provoke contemplation and critical reflection on listening, hearing, auditory habits and sound culture or history by conscious manipulation of the medium and its social signification. Using a new sound device as an artistic medium, we hope to encourage curiosity and reflection about these concepts. Spatial sound reproduction techniques can be classified as either (1) perception simulation (binaural sound, L-channel stereophony [5], etc.) or (2) sound-field simulation (wave field synthesis, classic Ambisonics, etc.) [6]. Beamforming (BF) technology belongs in the second category. However, while it is a generic technique commonly used in such areas as medical ultrasound scanning, ultrasound scan, ground exploration and sonar, research on the use of BF for innovative sound reproduction has just begun [7]. The only commercial BF device available at the time of writing is for a conventional purpose: virtual 5.1 surround sound (Yamaha's Digital Sound Projector). Much remains to be explored when using BF for spatial sound within an artistic context.

2.2 Artistic intention: private and public spaces, spatial sound technologies, acoustic arenas

According to the "Psychology of space" [8], our spatial relations towards our environment are organized in concentric shells. The most extreme shells are

1. The home (or intimate/personal/conversational shell): a personalized space open to free expression of private activities, actions, movements and thoughts. The archetypal private or semi-private space.

2. The city (or public shell): an anonymous shell where spontaneous actions, movements and expressions are subtly controlled e.g., personal scheduling according to transport timetables, paying for transport, managing agendas with respect to institutions' opening hours. The archetypal public space.

Different auditory tactics, listening strategies and auditory expectations characterize these shells. We are not listening the same way when we are in our bathroom or an airport terminal [9]. Different auditory tactics come into play when listening to a friend in a crowded café, on a mobile phone or in a quiet living room. Listening strategies are also affected by their cognitive context, e.g., job- or performance-related (pilots, telegraph operators, etc.), or leisure-oriented listening. Technological devices also participate in the creation, or variation, of new auditory tactics on the basis of previous auditory experiences, tactics and sonic cultures [10].

These definitions of environmental shells concur with the auditory spheres as introduced by Blesser and Salter in their presentation of acoustic horizons and arenas [11]. An acoustic arena is defined as a region where listeners share the ability to hear a given sound source. Typically, each auditory sphere involves different types of acoustic arenas, or sound sources. While navigating socially through these spheres, the expectations about acoustic arenas trigger or emphasize various auditory tactics, communicative behavior and sound quality or aesthetics. As mentioned by Blesser and Salter: "Social expectations determine the properties, especially size, of an acoustic arena and social behavior then adapts to available arenas. [...] Aural architecture [which participate in the creation of acoustic arenas] is not only the physical design of a space, but also part of a complete social system." We believe that, just as aural architecture does, spatial sound technologies for public spaces also take part in a complete social system. Since acoustic arenas influence social cohesion, technological modifications of acoustic arenas is, perhaps, the most salient feature of sound devices that aim at the cohabitation of private and public auditory spheres.

In accordance with these conceptions, our intention was to interfere and play with the auditory tactics used in a public space by diffusing spatial sound usually associated with private spaces. We wanted to exploit these interferences as an aesthetic effect, an exploratory avenue, a conceptual tool and an artistic statement to encourage auditory spatial awareness and critical reflection concerning the technologies which contribute to the social shaping of listening and hearing. Technological devices which, by their banality [12], surreptitiously intrude and modify our habits. BF technology can manipulate the regions of space where sound is audible by shaping and controlling the spatial and directional radiation of sound. It can create and manipulate acoustic arenas intended for the spatial cohabitation of the intimate, personal and public spheres. The creation and restructuring of these acoustic arenas and communities has already been initiated by technologies such as portable headsets and mobile telephones. Unlike these two examples, in Auditory Tactics, BF is used to create a private sonic space remotely.

However, as developed by Sterne [13], these ideas should be treated with great care. Such a fragmentation of the acoustic arena in private acoustic arenas is not solely or deterministically related to technological devices and innovations. Indeed, various private-space listening techniques with few technological supports already existed prior to personal sound devices as those mentioned in the introduction. One should also keep in mind that prior cultural contexts participate in the selection and shaping of emerging technologies, which are often the more or less conscious product of collective wishes and futuristic visions. On that matter, the analytical program proposed by Sterne in "The Audible Past" poses the possible bases and articulations of a technology-related art practice which operates in sound arts. Under that influence, we hope that our approach proposes an equilibrium between historical, cultural, artistic and technological vantage points. Indeed, our artistic practice involving technological devices and innovations is usually based on a conscious mix and superimposition of many aspects, references, sounds, etc. so that from an accumulation of elements a critical interpretation might appear within the audience without predetermined meaning or very specific direction. As the sharing and discussion of multidisciplinary knowledge about investigated technological devices is part of our artistic intention regarding the critical understanding of sound technologies, this paper also contributes to our artistic agenda. Next section introduces to the technical aspects of the BF technology.

2.3 Sound beams

An acoustical beam is a sound that propagates with a hyper-directive radiation. BF relies on loudspeaker arrays (Fig. 1) to create such beams.

In order to understand this technology, let us first assume that a loudspeaker emits a spherical wave [14]. Examples of spherical waves emitted by loudspeakers are shown as dashed lines in Fig. 1 (a) for L = -7 and L = 0 (where L is the loudspeaker index). We next recall that the total sound field created by a set of sources is simply the addition of the individual sound fields created by each source.

The basic idea of BF is to use a loudspeaker array with a delayed emission for the individual loudspeaker to create directive radiation. Fig. 1 (b) illustrates the process. Each dashed line represents a wave front created by a loudspeaker. The emission order is indicated: L = -2 emits first and L = 5 emits last. In this figure, it can be seen that the wave fronts are aligned in space for the angular direction jbeam (beam direction). This alignment (thick black lines) corresponds to a constructive interference: all the individual wave fronts add up to create a stronger wave front. For other directions, the wave fronts are not aligned and interfere with one another: the sound radiation shows a lower sound level. Fig. 2 shows an emission of three consecutive impulses by a single source and by an array. Note that while the sound amplitude is stronger in the beam direction, there is some softer residual sound radiation in all directions. The signal processing for

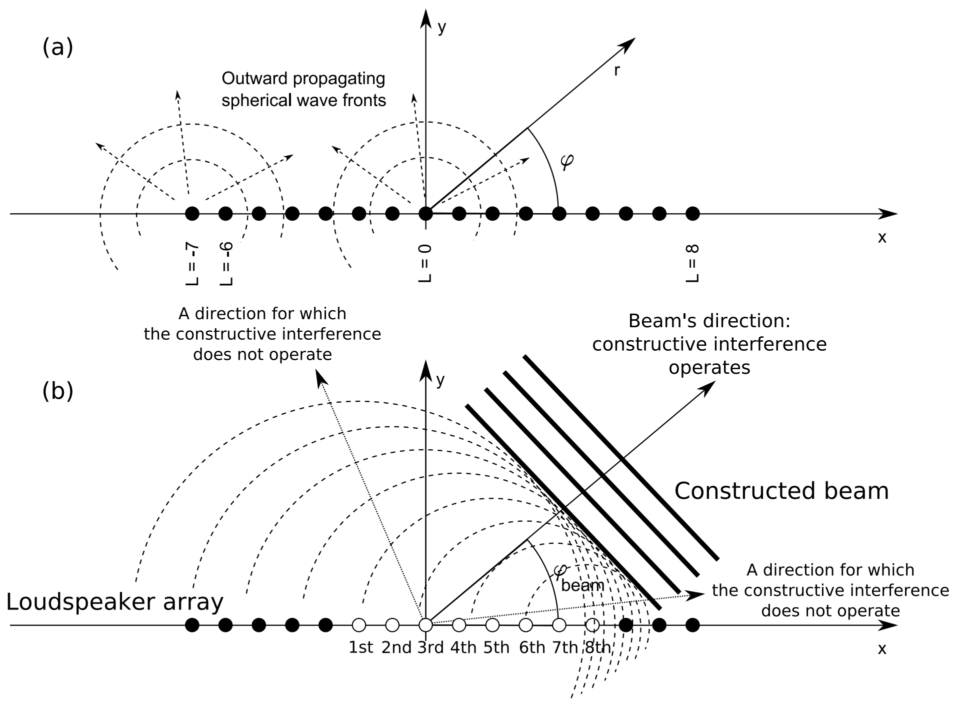

Fig. 1: (a) Linear 16-loudspeaker array. Loudspeakers are marked by filled circles. Position is described by rectangular (x,y) or polar (r,j) coordinates. Wave fronts created by individual loudspeakers are marked by dashed lines. (b) Scheme of sound beam with 8 loudspeakers (white circles). The order of emission is indicated.

beamforming is illustrated in Fig. 3 [15]. The cascaded delay modules have the same time delay. Varying this time delay will rotate the beam. The time delay corresponds to the time needed for a plane wave with propagation angle jbeam to propagate from a given loudspeaker to its neighbor. We used a time delay of D = d cos(jbeam) / c where d is the loudspeaker separation distance and c the speed of sound (344 m/s).

This signal processing algorithm was achieved in real-time using Pure-Data. We experimented with 8 audio channels assigned to 8 beams. The array is shown in Figs. 4, 5 and 8.

3 Creation Process

3.1 Sound material

At the heart of what we wanted to express with Auditory Tactics stand the selection and transformation of sound material in relation to our interest, that is, the intertwined influences of augmented

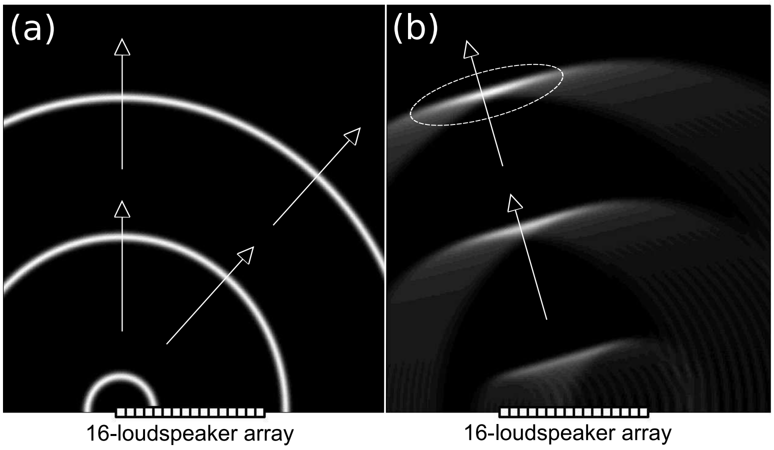

Fig. 2: (a) Snapshot in time of the theoretical sound field (three consecutive impulses) produced by a single loudspeaker. (b) Snapshot of the sound field produced (three consecutive impulses) by a beamformer (jbeam=105 degrees). Radiation is directive: there is an intensification of sound in a given direction (marked by white dashed line), the illumination zone.

listening and sound projection technologies in reshaping their users' daily auditory tactics. The human voice, as a primary sound material, was an obvious choice to evoke the private or personal sphere while still maintaining a relation with the public space. Indeed, although criticized by Sterne [16], speech is generally perceived, on a broad sense, as the manifestation of a kind of "pure interiority," the primary site for the individual.

Auditory Tactics involved a total of 941 original samples grouped in 31 thematic banks. These banks spanned across a variety of sounds: men and women breathing, whispering, laughing, screaming and speaking in shrill voices, various vocal sounds or effects, vocoder voices, drones and short text excerpts from various authors. The excerpts were related to the place of the individual or institutional voice in public space and the coercive control of voices and acoustic communities. A fine balance between concrete realism and musical acousmatic treatments was attempted.

3.2 Generative composition

The exhibition took place in the public hall of the EV (Engineering and Arts Faculty) Building of Concordia University (Montréal, Canada) from August 22nd to September 22nd 2007, with continuous access. We were consequently concerned with the creation of a generative sound composition [17] that would stimulate listening over the entire exhibition time. We had explored generative sound composition in previous works [18]. Generative composition operates at the macro level of the composition to design large-scale compositional processes without composing every detail.

We created a macro-scale structure based on a 24-hour cycle. Six time periods were created: each relied on different sample banks and involved a different implementation of sampler control and adaptive mixing.

Night time was a combination of soft breaths and intimate, soft sounds. Morning sounds were a continuation of the night with murmurs, laughs and more active sounds. It was an intimate, proximate and gentle awakening. At noon, these soft and natural sounds were replaced by vocoder

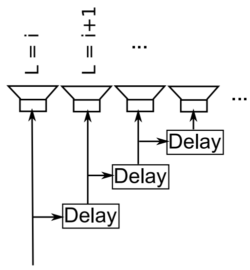

Fig. 3: Schematic representation of a cascaded-delay chain for beamforming.

and synthetic voices (whispers, sometimes with amplified drones) that read a plethora of text excerpts. Shrill voices and groans invaded the afternoon with a hint of uncertainty, stress and revolt. Following this progression, the evening was characterized by more intense and impulsive sounds, voices and marked screams, with synthetically altered voice sounds. The evening reconnected to the nocturnal over a long progressive transition from excitement to blackout; a deep sleep.

3.3 Public space

The EV Building is located on St-Catherine Street, one of the busiest axes of downtown Montréal. The hall is occupied and traversed by arts and engineering students as well as a variety of profiles coming and going from the building basement which hosts a subway station, a gym and small stores. Figures 4 and 5 picture the loudspeaker array at Concordia. The selection of this site for the public presentation of Auditory Tactics supported our conceptual interest. It was the archetypal public space that allowed us to implement our artistic intentions. However, this type of public space also came with factors that constrained the logistics of the project: including security, administration, planning and scheduling.

3.4 Spatial sound effects

We were initially interested in investigating two particular spatial effects (Fig. 6). The first effect uses BF to remotely create private sonic arenas in a heterogeneous sonic space to challenge the default auditory tactics of people immersed in various sound beams. Two beams scanned the space (from -90 to +90 degrees) while two beams were fixed to angles close to 0 and 180 degrees. People within these illumination zones received a sonic content about 16 times louder than people in shadow zones. This effect was used to materialize the idea of superimposing the private auditory sphere to the public one. People in viewing distance of each other had private, personal, access to different audio contents and loudness balances.

The second effect exploits the reflexivity of the beams. The array was placed in an alcove above eye level and six sound beams were projected against the facing wall. An example of a bouncing illumination zone is shown in Fig. 6 (b). Depending on which illumination zone (direct or reflected) the listener stood in, the perceived sound source was localized as the array or the reflective surface.

Fig. 4: Installation at Concordia University. The picture shows the architectural complexity.

The expected result was that the audience would perceive the sounds as if they were emanating from the walls (either from static or moving reflection zones).

4 Results, observations and future perspectives

4.1 Results

4.1.1 Beamforming

Preliminary listening tests in Vidéographe's space confirmed the existence of sonic illumination and shadow zones. The transition from illumination to shadow was progressive and continuous as illustrated in Fig. 2. Theoretically, the illumination zone (in the beam) should involve a 12 dB gain in comparison with the shadow zone (outside the beam), that is 16 times stronger (using 16 loudspeakers). The fact that the illumination and shadow zones differ by 12 dB might deceive the most informed part of the audience who tend to imagine sound beams more sharply extruded in space. However, the separation of public and intimate auditory spheres along the sole auditory modality does not compare with the sharpness and brutality of optical, thermal and acoustical isolation provided by a wall. The remote creation of sound boundaries and the delimitation of intimate and public sonic zones without walls is inherently complex and difficult. However, within

Fig. 5: Installation at Concordia University. FOFA (Faculty of Fine Arts, Concordia University) Gallery Vitrines: Jessica Auer and Andreas Rutkauskas, photography.

the context of this installation, a 12 dB gain proved to be sufficient to efficiently explore the spatial effects and themes described earlier.

4.1.2 On-site perception of sound beams

As expected, the passersby were surprised by the sounds they perceived that did not fit with the public space they were in. Intrigued, they typically searched for the source of these sounds. It was found that the audience had to be informed about sound beams in order to perceive the beam illumination and shadow zones as such. Indeed, such information tends to encourage active listening. The interaction of the beams with the architecture was more clearly and readily perceived when listeners were informed about what they should listen for. Listeners typically experienced the installation as a spatial sound with a special interaction with the building, i.e. positioning sounds in surprising places, or simply blurring the sound localization.

One of the most interesting effects obtained was the whispering wall. When a listener stood close to a wall exposed to a sound beam, the wall appeared to softly whisper the projected sound, giving a strong impression of intimate listening. The sound localization was completely dissociated from the array. This phenomenon is illustrated in Fig. 7. When the listener stands near a wall, he or she is exposed to the direct sound from the array (beam imperfections) and to the reflected beam from the wall. The direct sound reaches the listener's ears first. The reflected beam arrives just milliseconds later. The greater amplitude of the beam reflection (illumination zone) may then

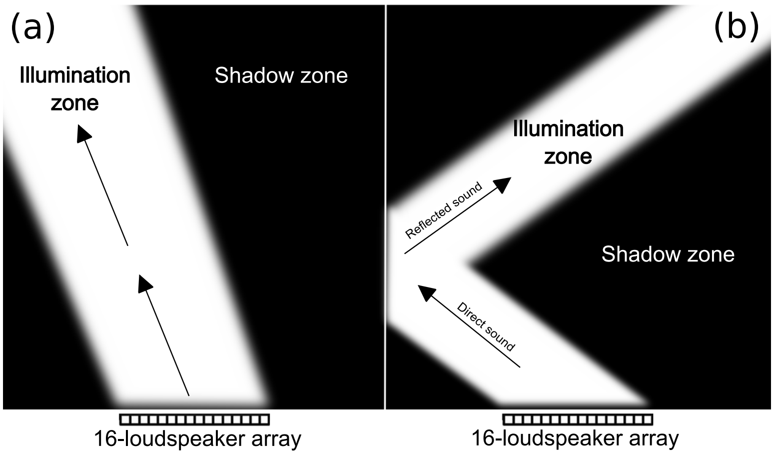

Fig. 6: Spatial sound effects: (a) Illumination and shadow zones, (b) Sound localization on reflecting surfaces.

circumvent the precedence effect [19]. Consequently, a listener located in the encircled region (Fig. 7) may localize the sound anywhere between the direct wave front incidence and the reflected BF wave front incidence. The synergy of this technical artifice and our artistic intention was clear as soft whispering typically reinforces the idea of private acoustic arenas and spheres. This whispering effect should be further explored in future beamforming experiments.

4.2 Analysis of the results

Several factors influenced the perception of the piece. Firstly, we observed how the soundscape of the hall influenced the auditory spatial awareness of the listeners. As the level and complexity of the original soundscape increased, the attention competition between the investigated soundscape and the sound installation rose as well. It is clear that the spatial smoothness of the transition between illumination and shadow zone was not drastic enough to surprise the passerby. It would take more than a 12 dB difference to be able to dilute the sound in the background noise while making it strongly audible in the illumination zone. Secondly, the intricate generative sound composition and the use of eight simultaneous sound beams created a complex spatial sound entity that uninformed audience tended to experience as a whole. While creating a rich experience of spatial sound, this may have hidden the transitions from illumination to shadow zones.

Architectural factors were also influential: the corridor shape of the hall created zones where the audience was as far as 30 meters and as close as fewer than 5 meters from the array. When listeners were close to the array, the effects previously described tended to reduce: sound seemed to come from the array. A consistent array-listener distance would be interesting to explore. As the relative distance augmented, the perceived richness of the interaction between the beams and the architecture increased: sounds were localized as moving and sliding on surfaces.

Visibility of the array was detrimental: when one sees the loudspeaker array, spatial sound impression of sound emanating from reflecting walls can be annihilated. The human brain tends to combine vision of sound sources with sound localization (i.e. the ventriloquism effect, the justification for the monophonic central voice channel in sound for moving images [20]). However,

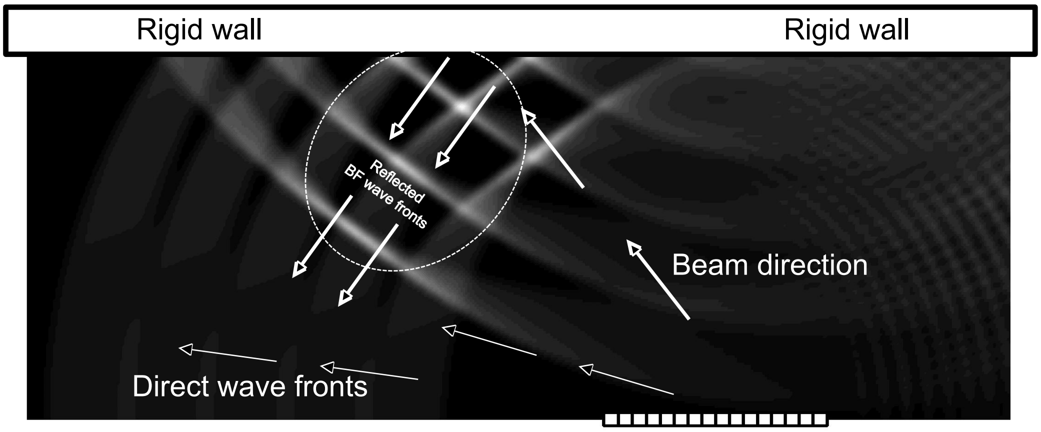

Fig. 7: Walls influence the sound localization.

subtle integration of the array with the hall prevented many passersby from visually identifying and localizing the real sound source.

According to our own experience, the sound beams were also localized on ceilings, corners and other surfaces. In particular, sounds projected by beams with a pivoting axis were clearly perceived as sliding on the walls and corners. The most intense effects came from very long samples (without any drastic or repeating onsets) that had a noise component: time-stretched breaths or drones. As the number of simultaneous sounds increased, the effect was reduced. These results allowed us to identify several axes for future work.

4.3 Future avenues

In order to improve perception of the sound beams and to enhance the reception of the installation, four axes need further exploration:

1. Simplification of the composition and sound material. What stems from the project is the influence of the complexity and density of the sound composition on spatial sound perception and vice versa. Simplification of the composition might contribute to greater clarity of the acoustical beams as peculiar spatial sound entities. This is a matter of how active, attentive and sensitive the listener is. For public space, it can be assumed that these are diluted.

2. Modifications of the loudspeaker array. It would be interesting to increase the directivity of

Fig. 8: Fabrication. The final array in the Vidéographe's PARC.

the beams and the intensity differential between illumination and shadow zones.

3. Type of space investigated. Future presentations would need careful selection of an exhibition space, the relative position of the architectural surfaces to the loudspeaker array and the relative position of the audience to the loudspeaker array. According to our experience, spatial sound effect and perception with beamforming in a given space is difficult to predict; direct experiment is mandatory.

4. Alternative spatialization settings. A further influencing factor on the reception of the piece is the complexity of the spatialization. It would be interesting to reduce the number of beams to one unique one.

These are only some of the possibilities we envision for future versions of Auditory Tactics.

5 Conclusion

The conquest of sound space as a commodity, possibly subject to personalization, privatization and merchandising, implies its division, its fragmentation, and its specialization. Technologies and products such as Walkmans, MP3 players and mobile phones all allow for a private sound space to be superimposed on, or to override the public sound sphere. This encourages the deployment and creation of private auditory tactics on top of or instead of public ones. However, these technologies, along with the reshaping of the auditory tactics, both serve and participate in an intrusive and pernicious agenda: reshaping private sound as a commodity. Sound technologies are not only acting upon social practices: they also stem from social practices and desires [21].

With Auditory Tactics, we questioned this fragmentation and superimposition of sound spaces with the assistance of technological means. As such, the installation offered a reflexive perspective on this phenomenon through an artistic medium. The Beamforming technology was fundamental to support this artistic proposition. We believe that such non-utilitarian, artistic and hacked use of new technologies must be pursued to alleviate the otherwise commercial, economical and technological determination of such technologies' identity. This is particularly the case with a technological device that is just making its way out of laboratory to become a socially absorbed media. Auditory Tactics is also a cultural and political intervention aiming to critically participate in the collective and cultural understanding of the device [22]. This positioning is at that heart of our artistic statement and orientates much of our artistic work using technological devices and knowledge.

Characterized by the separation between illumination and shadow zones and interaction with architectural surfaces, beamforming opens new avenues for spatial sound composition. We are eager to observe and participate in future developments of this promising artistic project.

On practical and artistic fronts, there is a need for further exploration of interaction between the loudspeaker system and various architectural spaces. Besides public space, concert halls and rooms used for electroacoustic or sonic art displays could be stimulating sites for further experimentation. Within the fixed time frame of the Auditory Tactics residency, we got only a glimpse of the possibilities. Hence, the stimulating future.

6 Acknowledgments

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8 The Authors

Dr Philippe-Aubert Gauthier is a post-doctoral fellow at the Groupe d'Acoustique de l'Université de Sherbrooke where he pursues research on sound field and sound environment reproduction. Dr Gauthier is a self-taught audio artist. His art and musical works have been presented in Canada, the USA, Mexico and Europe.

Dr Philippe Pasquier is assistant professor at the School of Interactive Arts and Technology of Simon Fraser University's Faculty of Applied Sciences (Vancouver, Canada). He is conducting both a scientific and an artistic research agenda.