SPECIAL SECTION INTRODUCTION

The Institute of Sonology

In 1956, a studio for electronic music was opened within the acoustics department of Philips Research Laboratories. The productions made in this studio emphasized functional music for (animated) film, ballet and exhibition areas and "popular" music for gramophone records.

Philips decided in 1960 that the Research Laboratories could no longer house a studio, which was becoming more a workplace for composers and less a means of meeting direct corporate needs. After exploration of the possibilities for continuing the studio with various organizations, it was finally transferred to Utrecht University, where it was housed in a small portion of the Atlanta building on the Plompetorengracht. Initially, there was significant influence from Philips and no clear artistic direction.

In 1964, Gottfried Michael Koenig became artistic director of what was originally called Studio for Electronic Music (STEM). Under his leadership, STEM grew to be a studio complex that occupied the entire Atlanta building and achieved fame as an institute for production, education and research.

International attention to the institute increased in 1971 with the arrival of a PDP-15 computer, which was used to develop programs for algorithmic composition and digital sound synthesis. Computer programs such as Project 1, Project 2 and SSP (by Koenig), PILE (Paul Berg), MIDIM/VOSIM (Stan Tempelaars/Werner Kaegi) and POD (Barry Truax) are landmarks in the history of computer music.

In the area of voltage-control technique in the analog studios, The Institute of Sonology continued to design and build new equipment. This tradition continues today and interfaces for live electronic music are designed and built in the electronics workshop as well.

In 1986, the Institute of Sonology was incorporated into the Royal Conservatory in the Hague. In addition to the 1-year course, a 4-year conservatory major and a 2-year masters program are offered. The educational program deals with: electronic music production, digital sound synthesis, algorithmic composition, computer programming, spatial concepts of sound, field recording, sound installations, voltage control technique, live electronic music, psychoacoustics, history of electronic music and music theory.

Today the staff of the Institute of Sonology of consists of: Richard Barrett, Justin Bennett, Paul Berg, Raviv Ganchrow, Johan van Kreij, Peter Pabon, Joel Ryan and Kees Tazelaar [1].

The papers selected here were written by former students of the Sonology Masters program as part of their final examination. I have selected them on the basis of their quality and originality, while at the same time intending to present an overview of some of the key elements of the Sonology curriculum: algorithmic composition, sound synthesis and spatial aspects of sound and sound reproduction. Particularly of interest to me is the fact that all these writers' research has great influence on their practical work as artists. It drives them into unknown territories while at the same time providing them with a framework and criteria to give their explorations a clear direction instead of amounting to a mere "wandering around."

I hope that the readers of *LMJ* will enjoy these papers as much as I have.

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Kees Tazelaar (born 27 July 1962) studied at the Institute of Sonology and at the Royal Conservatory in The Hague, graduating in 1993. Since then Tazelaar has taught at the Institute of Sonology, becoming head of the institute in June 2006. His work is dedicated to electronic music for fixed media in various multichannel playback formats and wave field synthesis. In addition to his own works, he has contributed to music-theater projects by Dick Raaijmakers and Theatergroep Hollandia. He has also produced reconstructed versions of compositions by Gottfried Michael Koenig, Jan Boerman, Edgard Varèse, Iannis Xenakis, György Ligeti and Luctor Ponse. During the winter semester of 2005–2006, Tazelaar filled the Edgard Varèse guest professorship at the Technical University of Berlin. See also <www.keestazelaar.com>.

Note

1. For more information see <www.sonology.org> and <www.koncon.nl>.

SPECIAL SECTION

Perspectives on Sound-Space: The Story of Acoustic Defense

Raviv Ganchrow

ABSTRACT

The late 1920s yielded the development and construction of several large-scale "sound mirrors," along the southeastern coast of Britain, aimed at intercepting sounds of approaching aircraft outside the visual range. A central mode in the design of these long-range listening devices emphasizes a sonic paradigm in which frequencies are considered in terms of corresponding physical sizes. By examining the case of the sound mirrors as a formative moment within the broader reconfiguration of listening habits, the author attempts to locate a shift in the grasp of space that occurs when an optic model of viewing is replaced with an acoustic model of listening, exposing a condition in which the close-at-hand and the far-off momentarily coincide.

Armatures of Listening

Today's epistemologies of listening are not part of a premeditated advancement but rather the results of cultural and social habits formed in immense fragmentary fields of interaction [1]. Although it can be said that the physiological capacities of the ear are for the most part unchanging, the scope of "listening" remains fundamentally vague. "Listening," in terms of attention-to-sounds-heard, inherently expresses the categories we choose to extract from audible (and inaudible) eventfulness. Tuning in to such categories may also reveal the meanings we tend to reversibly invest in matters of vibrations.

A history of listening (if such a history could ever be palpably revealed) would demonstrate the extent to which the characteristics of our audible worlds are historically and contextually constituted [2]. An attempt to decipher the contemporary armatures of listening would no doubt unfold along mellifluous and unpredictable lines, tracing the unintentional undercurrents set forth in the wake of pragmatic innovation. It is my hunch that in order to grasp such modalities of "sonic attention" it is imperative *not* to separate the cultural and scientific fields in which sonic attitudes are formed but rather to investigate the eclectic domain of practices, artifacts and peripheral influences operating upon the malleable structures of listening. The following account of acoustic defense provides a compelling artifact from our audible past—one in which particular configurations of listening are created in the development of long-range listening devices placed along the southeastern coast of Britain. I propose to consider this example as a solitary instance within much broader reconfigurations of listening occurring in the late 19th and early 20th century.

Acoustic Defense

During World War I, and in the years leading up to World War II, Britain was involved in a wide-scale project of acoustic defense [3]. The research aimed to locate enemy gunfire and aircraft movements by way of various listening devices. In this footnote to military history, there is only a minor role delegated to electronic technology; instead, research focused on the physical acoustics and reflective properties of rigid surfaces. Before the advent of sophisticated radar detection systems, surveillance was limited to information gathered directly by way of sight and hearing, and these initial sound-ranging devices extended the in-built listening capacities of the human sensory apparatus, at times to the scale of buildings.

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This article is an excerpt from "Sound-Space," the author's thesis presented at the Institute of Sonology, Den Haag.

Architecture's acoustic focusing capacities have been known since the examples of "whispering galleries" from antiquity. Sound transmission along curvilinear structures at times converges into focal zones due to the reflective properties curved surfaces exert upon fluid dynamics. As early as the 1922 edition of Wallace C. Sabine's *Collected Papers on Acoustics*, it is stated that even a standard wall surface will reflect, on average, 96% of the incoming acoustic energy, in contrast with the best silvered mirrors, whose reflection of light rarely exceeds 90% [4]. In the example of a dome, which approximates a sphere, any source sound that is transmitted from the center will create an echo that will refocus at the center point almost without energy loss.

Numerous examples of whispering galleries have been documented as far back as the 4th century BC, when an *S*-shaped cavern at Syracuse, Sicily, was said to have been used as a pan-aural prison [5]. Along the apex of the cave runs a conical duct leading to a concealed room at the far end of the cavern, wherein all the reverberating sounds of the prison could be heard. The surveillance principle echoes the more familiar example of Jeremy Bentham's Panopticon prison yet it is founded upon aural capacities instead of those of vision. Despite the prospects of intentionally incorporating such properties in architectural design, most examples of whispering galleries are thought to be flukes of construction

Fig. 1. Acoustic reflective properties of a 20-ft sound mirror at Abbots Cliffs. (Illustration ©Raviv Ganchrow)

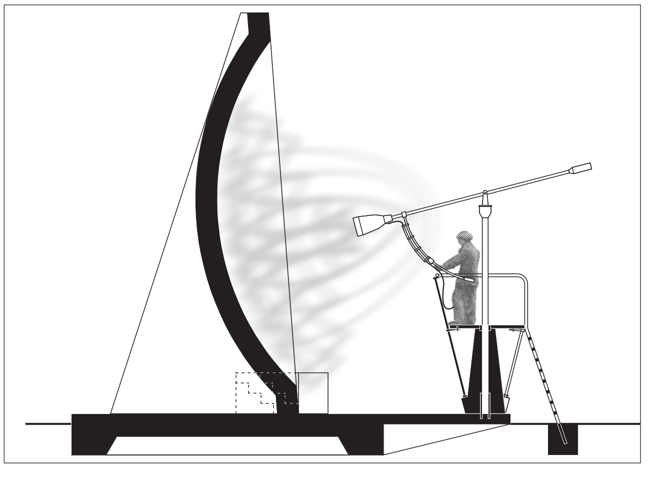

Fig. 2. 200-ft sound mirror at Denge, Kent Coast, U.K., 2005. (Photo © Raviv Ganchrow)

rather than premeditated intentions of design. Even in the case of the "Dionysian Ear" mentioned above, the cavern originally functioned as a quarry and was only later reputedly converted into a prison.

In this sense, Britain's acoustic defense project is exemplary of premeditation in that it constitutes a deliberate attempt to harness airborne vibrations by means of construction. In contrast to the case of whispering galleries, the development of acoustic sound mirrors incorporated a refined understanding of sound-wave propagation and reflection, oriented toward a narrowly defined subject of reception, namely, a certain range of wavelengths. Two types of listening dishes were developed over the course of the project: One was deeper, with parabolic properties; the other shallow, with spherical curvature [6]. In order for them to function properly, sounds had to arrive perpendicular to the opening of the parabolic dish, while the mirrors based on spherical sections were able to pick up sounds traveling obliquely to the surface of the dish. These defining characteristics led, on the one hand, to the development of rotating parabolic dishes, adjustable to the direction of incoming signals, and on the other, to the construction of large fixed dishes called "sound mirrors." The first documented fixed construction sound mirrors in Britain's acoustic defense project date to around 1915 [7].

Stationary sound mirrors were conceived as part of an early warning system, operating as long-range listening devices aimed at intercepting sounds of approaching aircraft outside the visual range. The problem the project sought to overcome was that of amplification: By the time distant aircraft sounds had reached the coast, the propeller and engine rumble had faded to such an extent that it was no longer audible to the naked ear. The solution was somehow to collect the incoming vibrations and refocus their energy back into audibility. This was done by means of the reflective properties of curved surfaces. Waves reflected off the concave spherical surface of such a mirror form a hemispherical zone of wave enhancement midway between the mirror's center of curvature and the surface of the dish, called the *caustic*. Any incoming signal becomes focused at a point upon the caustic that sits perpendicular to the incident angle, extending along a line that passes through the center of curvature.

Nearly all the mirrors built along the narrow stretch of Britain's coastline, from Suffolk in the north to Dungeness in the south, were based on spherical section design. Initial attempts at long-range listening began at Joss Gap, where bowl-shaped excavations were directly carved out of the chalk cliffs as early as 1918. Later efforts were focused at Hythe, Abbots Cliff and then Denge, on the Kent coast, in what was to become the headquarters for the Air Defense Experimental Establishment. In the marshlands extending toward the seaside, an assortment of freestanding cast concrete dishes were constructed and tested, including a 20-ft version and a 30-ft half-sphere "listener," complete with a submerged listening chamber and rotating funnel. From within the chamber, personnel could scan the mirror's caustic by way of the funnel, channeling sound through an attached stethoscope (Figs 1 and 3).

Of primary concern for the designers were the frequency components emitted by the aircraft. Thus, the dramatic scale that these concrete dishes attained was directly related to the physical size of the frequencies that the dishes attempted to detect.

> It has long been known that the most penetrating sounds for long distance transmission are the lowest pitched sounds with the greatest wavelength. Whereas the 30 ft. mirrors are very efficient for waves up to 3 ft. or so, corresponding to the middle of the pianoforte scale, the sounds we wish to deal with have waves of 15 to 18 feet, and tend to become inaudible to the ear. This involves the extension of mirror surface to about 10 times that hitherto employed. The other dimensions are to be extended 10 fold. . . . Since for long distance listening of this type the elevation angle will be small, the vertical mirror dimensions can be reduced [8].

In other words, the dish structures were literally tuned to the physical size of the enemy aircraft's fundamental frequencies; these being deep rumble tones with superior transmission properties. To effectively pick up these 15- to 18-ft-long wavelengths, the equivalent of approximately 60–70 Hz [9], the most ambitious construction project was undertaken within the development of sound mirrors. In 1929, a 200-ft strip sound mirror, 26 ft high, with a double radius of a curvature of 150 ft and flanked by a sloping forecourt, was erected at Denge (Fig. 2). The surface area of this concave wall was extended to such a size that the swinging funnel collector and stethoscope used in previous constructions were replaced by a patrol of walking listeners.

The forecourt of the strip mirror was divided into triangular patrol zones corresponding to ranges of azimuths, extending out over the open sea. The focal point of incoming sounds was determined to occur along a designated arc at the front of the structure. Each quadrant was to be silently patrolled by a trained listener equipped with rubber shoes and nonabrasive clothing. Additionally, a retaining wall was constructed at the front of the forecourt to reduce wind noise. One report even describes "lateral canvas curtains" that were to be placed on either side of the mirror to further reduce incidental noise. No photographic records support this claim, but one can only imagine the curious ceremonial appearance of the fully operational site.

The early 1930s marked the peak of

military acoustic research. After the completion of six large-scale mirrors, a proposal was drafted for an extensive early warning network, with mirrors placed at 16-mile increments forming a "listening shield" extending from East Anglia in the north to Dorset in the south. However, the plan was never realized. In fact, sound mirrors never developed beyond the experimental stage due to the discovery of a more powerful means of aircraft detection. In 1936, an airplane flying along the coast of Norfolk was pinpointed by means of Radio Direction Finding (RDF) at a distance that far exceeded the range attained by the mirrors. This event effectively sealed the fate of the acoustic defense project and announced the birth of radar.

Tactile Perception

The border occupied by the sound mirrors, between whispering galleries and advanced imaging technologies, arguably demarcates a paradigmatic shift in perceptual relations. A subtext to the development of the mirrors is the shift in observational methods away from the optic model of the telescope (wherein the eye is seen to extend into a "stable" landscape) to the radiant model of interferometry (wherein a point of observation becomes the anchor in an otherwise fluctuant zone of wave fronts). In the 200-ft mirror, knowledge of a distant aircraft materializes from within the tactile registration of vibrations literally brushing up against a listener's ears. To hear a distant vibration also meant to physically collide with that same acoustic event at a specific focal point along the caustic arc designated in the forecourt of the mirror, thus conveying a location of sound that was as much "here" as "out there." In this format of localization, an unmistakable sequencing of perception occurs—the undulating focal point of sound itself is primary, engaging the listener point blank, while at the same time producing a secondary reference that is then conceptually (instead of reflexively) projected back over the horizon toward a yet-to-be-seen coordinate. One curious outcome of this condition is the evocation of coexistent (or superimposed) spaces where the close-at-hand and the far-off momentarily coincide.

This condition subtly violates the normative symmetry hearing maintains in relation to vision, namely that of apprehension at a distance. When confronted with sound's physicality, the listener begins to occupy a double position. The outcome is a reorientation of correspondences between sound, temporality and perception whereby a "viewer" becomes a "listener," signaling a reorientation in the site of experience.

Importantly, an idea of space that was previously deemed to be the outcome of a network of relations between dispersed objects within a visual field is foreshadowed by the space of the interval itself—in other words a registration of the micro-spacing between successive fluctuations constituting an ongoing pulsation of appearances. Under the influence of the mirror, the commonsense Cartesian framework in which solitary, identifiable sounds are seen to occupy coordinates within an otherwise empty "space" subsequently dissolves into a more primary continuum of pulsating phased-space [10]. An understanding of sound as a pre-cognized state of crisscrossing interference patterns is embedded within the anatomy of the mirror itself. This trait of the mirror is established by considering frequencies in material terms and by imagining the peaks and troughs of vibration in terms of their corresponding physical sizes.

The idea of phased-space effectively opens a portal into an impalpable realm of acoustic phase interactions where the patterning of abstract wave undulations perpetuates a secondary spatiality emanating from coordinated acts of listening and where the "distant" is foreshadowed by an immersive space of sonic eventfulness. The outcome suggests a loosening of the meaning-reflex through which sonic entities seemingly coincide with their opto-spatialized sources of emission.

In terms of the "site" addressed by the structure of the mirrors, their technical functioning also serves to redefine their own architectonic extents: In this case the "tectonic limits" are broken open to include an extensive territory of influence. In architectural terms, the 200-ft strip mirror extends well beyond its visible form by plumbing a malleable space between the wall and a remote resonating object. The result is a structure that relates very precisely to an expanse 84° in width (the listening aperture width for this particular mirror design) and approximately 128 sec long (the time it would take an emitted sound from the furthest possible position in the listening range to reach the surface of the mirror); the territory that corresponds to the listening extent of the 200-ft wall. Such implicit territorializing of a seemingly "limitless" panoramic expanse is no better illustrated than in a map proposing the coordinated network of strip mirrors along the southeastern coastline of Britain (Fig. 4) [11].

Materiality of Frequencies

One apparent departure from prevalent sonic modalities embodied within the original sound mirrors relates to a spatial materialization of sound. The development of sound mirrors could not have been undertaken without a corresponding shift in thinking about sound outside of the way sounds are perceived—more specifically, toward thinking about frequencies in terms of physical sizes.

Once sound is conceived in its dimensional attributes, this also facilitates the

Fig. 3. 30-ft sound mirror at Denge, Kent Coast, U.K., 2005. (Photo © Raviv Ganchrow)

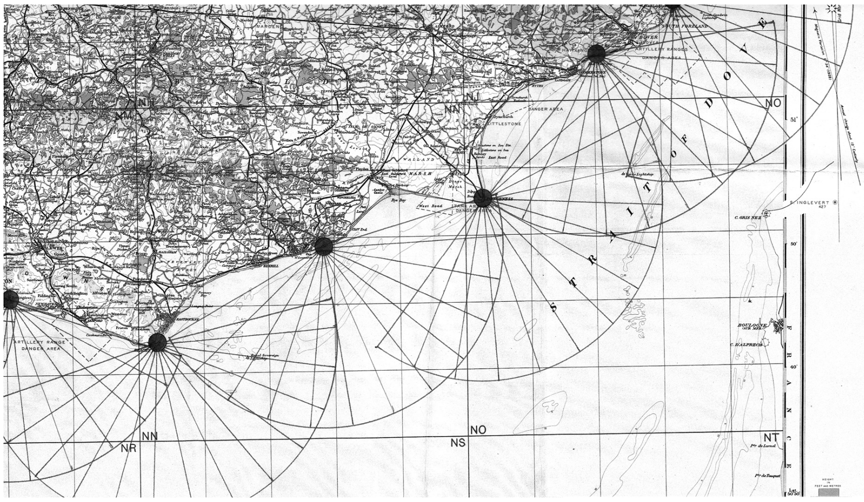

Fig. 4. Acoustic defense map indicating the location and listening extents of a coordinated coastal network of 200-ft sound mirrors. (Photo: The National Archive, Ref. AIR 16/317 [Sound Discs and Mirrors Development 1934 Feb.–1935 Nov.])

superposition of an imagined acoustic terrain back into our observable surroundings. The materialization of frequencies into actual ocular artifacts is in fact a trend that has played out extensively over the course of the last half-century, particularly in the development of visualization apparatuses employing techniques of wave reception and radiation (such as ultrasonography, radio astronomy and MRI). It is in this sense that interferometric techniques may find their early antecedents with the notable case of the sound mirrors, wherein the mechanism of wave reception still plays out at the scale of the body, and where techniques of reception are little more than a fine-tuning of echoic principles of reflection.

Admittedly, the more recent radiant technologies (ultrasonography etc.) no longer directly address the biological capacities of the human ear, yet nonetheless extend the spectral boundaries of "hearing" (at times bypassing the realm of acoustics altogether) while altering the significance of "listening-in." Such developments, I would suggest, exert pressures back onto our epistemologies of listening, consequently amending definitions of such categories as "sound," "place" and "space" [12].

EPILOGUE

Although in empirical terms the realm of acoustic fluid dynamics is rather well understood, the notion of a "space-of-sound" maintains an ambiguous status. This is particularly the case when approaching the terms of spatiality from the position of the listener. It is my current assessment that there is no singular (and certainly no "absolute") sound-space. "Hearing space" pertains to multiple notions of space, where each space corresponds to an alternate material understanding of sound [13]; furthermore, these spatialities do not necessarily subsume one another, let alone correspond to each other. The same practices that enlist sound as fundamental tend to perpetuate and sustain their latent spatialities as byproducts of their own implementation. In that sense sound-space is as multiple as the defining characteristics we choose to discern within audible (and even inaudible) vibration. Achieving an expressive articulation of spatial sound is to my view less a matter of innovations in audio technique and more a question of various degrees of listening. Sound's spatialities are approachable by adopting attentive attitudes toward those sonic sediments already in circulation within the social-cultural environment as well as by sharpening our own spatial-sonic definitions and, maybe most crucially, exercising an intention to significantly "listen to space."

References and Notes

1. This article presents an excerpt from "Sound-Space," a second degree thesis presented in combination with a multi-channel audio work entitled *Distance at an Unknown Scale.* The written portion of the thesis comprised two sections: first, an inquiry into the spatial guise of sound, and second, empirical research I carried out on wave field synthesis and re-synthesis over a 2-year period at the Institute of Sonology. While the latter portion of the thesis emphasizes a hands-on approach to spatial techniques of sound, I regard these experiments as directly related to the underlying theoretical concerns of the excerpted thesis chapter.

Some adjustments have been made to this excerpt, most notably revisions to the story of Britain's acoustic defense project based on my research undertaken at the site of the Denge mirrors in 2005, as well as some additional comments regarding the nature of hearing in relation to our techniques and practices of listening. Results from my research into the remaining sound mirrors at Denge were published in Raviv Ganchrow, "An Improbable Dimension," *Res: Anthropology and Aesthetics,* Vol. 49/50, 204–221 (2006). This research was made possible with the support of The Netherlands Foundation for Visual Arts, Design and Architecture.

In the original chapter, I examine a series of formative moments of what might be called "epistemologies of sound-space" in terms of their implications for such epistemologies. I emphasize instances in which ideas of sound overlap with concerns of space to forge a partnership-in-form. Examples include Venetian polychoral music, the sonic architecture of Athanasius Kircher and the 1958 Philips Pavilion, as well as more recent concerns expressed in the installations of Bernhard Leitner and the music of Alvin Lucier and Luigi Nono, among others. I have selected the rather oblique case of acoustic defense for its relative obscurity within the history of spatial acoustics as well as to support my intuition that if a space-in-sound is to be discerned, it is not located in an absolute space of propagating waves or the physiological capacities of hearing as much as it is focalized where the body and social contexts intersect and influenced by myriad peripheral aural practices extending well beyond commonly accepted borders of the "cultural."

2. For instance, an exhaustive account of interrelations between technologies of sound, building practices and the cultures of acoustics in early 20th-century America can be found in E. Thompson, *The Soundscape of Modernity: Architectural Acoustics and the Cultures of Listening in America, 1900–1933* (Cambridge: MIT Press, 2004). Such historically contextualized accounts of hearing lend compelling evidence for the malleability of listening.

3. Military research into auditory observation techniques, leading up to Britain's acoustic defense project of the 1930s, dates back to "gun sound ranging" experiments in the trenches of World War I. A preliminary description of these earlier developments can be found in N. Richard Scarth, *Echoes from the Sky* (Kent: Hythe Civic Society, 1999) pp. 4–10.

4. W.C. Sabine, *Collected Papers on Acoustics* (New York: Dover Publications, 1964) p. 260.

5. A description of the so-called Ear of Dionysius can be found in W.C. Sabine, *Collected Papers on Acoustics* (New York: Dover Publications, 1964) pp. 274–276.

6. The early dishes were carved out of the chalk cliffs or made of plaster. Later ones were made out of bronze, tin, steel, concrete and even wood (in disc and not dish form).

7. An early example of a sound mirror carved directly into the chalk cliffs at Binbury Manor, Kent, can be viewed in N. Richard Scarth, *Echoes from the Sky* (Kent: Hythe Civic Society, 1999) p. 17.

8. W.S. Tucker, report quoted in Scarth [3] p. 93.

9. One document concerning the mirrors at Denge includes a chart of aircraft models analyzed and calibrated in terms of their specific acoustic-fingerprint denoted in cycles per second. The attempt was to gauge the size of the vibrations produced by the propeller's friction with air, combined with the noise from the exhaust pipes of the aircraft engine. What is important to stress here is a conception of acoustic vibration in terms of the physical sizes of frequencies. *Long-Distance Listening with Sound Mirrors,* Document AVIA12/132 (London, October 1932) p. 14.

10. I use the term *phased-space* to assign a nomenclature to the spatial sound field seen from the position of the wave interactions themselves. It is a category that encapsulates both space and sound in a single description. Phased-space should not be confused with the term *phase space,* from mathematical analysis. It is my intention to emphasize the phenomenal underpinnings of phased-space.

11. For information on the coastal mirror network project see document ref. AIR 16/317, *Sound Discs and Mirror Development 1934 Feb.–1935 Nov.* (The National Archive, London). An acoustic defense map indicating the location and listening extents of a co-

ordinated coastal network of 200-ft sound mirrors is available at The National Archive, ref. AIR 16/317, *Sound discs and mirrors development 1934 Feb.–1935 Nov.*

12. An article published in *American Scientist* describes attempts at detecting gravitational waves in terms of "listening." Although these waves are expansions and contractions in space-time itself, the article repeatedly utilizes the word sound to describe such vibrations. It would seem that an abundance of methods for transduction (implemented in devices that can translate magnetic or electromagnetic fluctuations into audible signals or vice versa) has thoroughly prepared the way for an expanded notion of sound as an inclusive term covering the broadband spectrum of terrestrial vibrations. See C.J. Hogan, "The Sounds of Spacetime," *American Scientist* Volume **94**, No. 6 (2006) pp. 534–541.

13. Ideas and examples in support of this conclusion have recently been developed in Raviv Ganchrow, "Hear and There: Notes on the Materiality of Sound," *Oase 78: Immersed* (2009).

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Raviv Ganchrow completed his architectural studies at Cooper Union, New York, in 2000, and received a second degree from the Institute of Sonology at The Royal Conservatory, The Hague, in 2004. His practice focuses on interrelations between sound, place and listener, aspects of which are explored through sound installations and writing, as well as the development of sound-forming technologies such as wave field synthesis. Recent installations directly address contextual acoustics, expressing a notion of "place" that is constructed by way of frequency interdependencies. He has been teaching architectural design in the graduate program at TU Delft and is currently a faculty member at the Institute of Sonology.

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