

Flexible Audio Speakers for Composition and Art Practice

Jess Rowland

My current work explores how sound exists physically in the body, materially in space and as percept, all at once. As an artist, musician and scientist, I have been interested in disrupting the boundaries that separate our notions of the physical and the experiential, the present and virtual, of sight and sound. I am specifically interested in sound technology as a way to approach these dynamics more deeply: Are there alternative models of sound production that can lead to a different understanding of how audition and vision, physical material and the phenomenological realm, can be construed to create our experience? This question led me to the development of flat flexible speaker arrays—distributed, stochastic, continuous, multimodal, with potentially unlimited channels—and to the creation of artwork using these arrays as a material [1].

My work has much in common with that of other contemporary sound artists who explore the technology of sound production as a way to reveal the magic of sound in the world. My work drew inspiration from artists such as Paul DiMarinis [2], who creates installation work that carefully manipulates fire (e.g. *Firebirds*) and water (e.g. *A Light Rain* in collaboration with Rebecca Cummins) to generate the sounds of voices and music that lead viewers to a new sense of awe about the nature of their personal experience of sound, and Christina Kubisch, whose *Electrical Walks* use induction and specially designed headphones to allow users to discover sound from spatially distributed electromagnetic sources [3]. In each case, these works playfully confound our everyday notion of sound production, expand our awareness of the mystery of sound and, by extension, change how we relate on a fundamental level to auditory experience and our own awareness.

My work explores similar themes: These flat flexible speaker arrays confront the listener with an unexpected physical form of sound creation. Here, however, the material form of sound production acts as a vehicle to explore, question and confound specific boundaries between modalities of experience, especially the boundary between visual art and music.

FLAT SPEAKERS AS ART MATERIAL

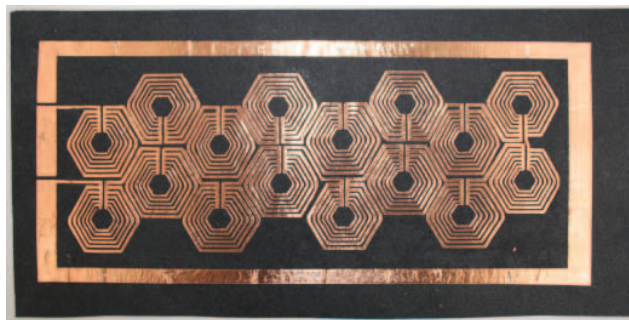
I primarily think of these flexible speakers as an art material. Rather than materials that only tangentially exhibit

sound-making qualities (such as traditional speakers or objects with speakers attached), I want to create material that is sound itself—to place sound in the foreground of material, rather than as a byproduct. The central notion is that a listener, a viewer, one who interacts, can approach sound directly as it is manifest physically and visually. This process is constrained—and made possible—by the physical laws that govern electrical sound production.

I create the flexible audio arrays using flat conductive materials that carry audio signals. The electromagnetic fields generated by these flat and flexible circuits then interact with a permanent magnet to generate sound, much like traditional speakers. I use conductive materials suitable for flexion such as conductive inks and thin foils. Flexible surfaces consist of magnetic strips, paper, foams, plastics such as clear acetate, and other lightweight materials that allow small rare-earth magnets or magnetic particles to be attached or embedded. I shape the copper foil circuitry primarily by machine cutting or by printing processes. Figure 1 shows a typical machine-cut array using copper foil adhered to paper.

Maximizing the boundary between the magnet and the circuit design is optimal for the strongest audio response. With this in mind, regular tiling of the magnetic material, such as Archimedean tiling of triangles or squares (as in Fig. 2) creates an efficient dense sheet of copper foil arrays on a clear acetate backing.

Fig. 1. Jess Rowland, flat hexagonally patterned speaker array using copper foil on construction paper, 4 × 8 inches, 2012. (© Jess Rowland)



The author presents a creative and technical practice using flat flexible audio speaker surface arrays. These arrays can be formed to various environments, offer diverse design possibilities and allow for user interaction. This practice provides an alternative to traditional models of sound reproduction by considering how visual and physical material could be construed as sound itself. Taken as art material, these surface array systems open up unique possibilities for acoustic spaces, composition and sound interactivity.

Jess Rowland (artist, composer), 1605 Martin Luther King Jr. Way, Berkeley, CA 94709, U.S.A. E-mail: <jessrowland@berkeley.edu>. Website: <www.jessrowland.com>.

See <www.jessrowland.com/art/electronicpaper-speakers/interactivity/> and <https://vimeo.com/67969655> for supplemental files associated with this article.

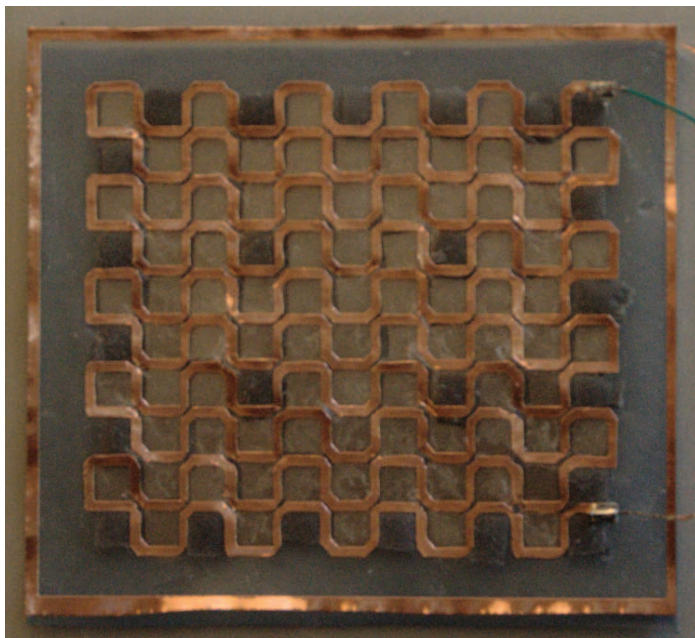


Fig. 2. Jess Rowland, flat speaker array with square tiling, using copper foil and flat square neodymium magnets on acetate, 4 x 4 inches, 2012. (© Jess Rowland)

I also wanted this material to be transparent, in the sense that nothing about the process is hidden; there is no black box (or, more appropriate to today's consumer electronics, *white* box). The technology is immediate; the disconnect so common to our contemporary experience between the material and the user is minimized. The technology used here is fundamental and legible. Nothing about the physics of this situation would be unfamiliar to an engineer from a hundred years ago. It is also materially light, unobtrusive and mostly recyclable.

Other researchers have developed paper circuitry from an engineering and design perspective. Most notably, Hannah Perner-Wilson has pioneered DIY paper speakers [4]. In the same spirit as her work, the technology explored here can be implemented by anyone with some basic supplies available at a local art store, rather than requiring industrial processes or expensive materials.

SOUND GLOVES AND GESTURE

If, rather than thinking of sound reproduction as a form of optimization for consumption, we think of it as a sufficient condition for the goal of engaging awareness, then these arrays can allow for alternate forms of interactivity, explorations of sound and composition.

By mounting the magnet that activates the speaker on gloves worn by the listener, I created an active experience in which gestures control sounds from the speaker array. These "sound gloves" consist of everyday gloves with a permanent neodymium rare-earth magnet attached (Fig. 3). Since there is no wiring involved

in the gloves themselves, users have full freedom of movement to explore the arrays. Sound is generated in proportion to the proximity of the user's hand to the array.

Sound gloves have been explored in other contexts, such as the *Lady's Glove* instruments made by sound artist Laetitia Sonami, which are used for performance and rely on sensors [5]. But the gloves presented here offer a different approach: Without data measurement or information control, this process provides an unmediated alternative to sensor technology. As an intentionally lo-fi alternative, the process can also

guide users to interaction points where the electromagnetic field is maximized, opening up possibilities for haptic and tactile feedback without the mediation of a control system.

This exploration coincides with the current interest of musical theorists in reexploring the role of the body and gesture in technologies of music making. Inspired by theories of embodied cognition, theorists such as Marc Leman have been interested in re-placing the body at the center as an essential mediator between the musical intention and our extended technologies [6]. Rather than employing technology that hides the relation between our physical experience in the world and the technological tools we use, here, gesture, movement and the body can once again be at the center of the dialogue about sound production.

COMPOSITIONAL FIELDS

With flexible speaker arrays, surfaces can be built up with multiple channels of sound output. Each sound channel can contain a different sound signal. When a person using a sound glove interacts with the surface, it becomes possible for different glove placement or different speeds or directions of movement of the gloved hand to generate different sound patterns. With more than one person exploring such a surface at the same time, the complexity of possible interactions increases exponentially.

This kind of interaction allows for a nondetermined compositional prac-

Fig. 3. A sound glove with neodymium magnet attached. (© Jess Rowland)



tice—compositional fields in which initial conditions are set up by the artist (e.g. the choice of the sound signals that can be discovered, the visual design that gives rise to their physical presence, the way those sound signals can change through time and the potential for the field to change its properties through interaction with people and the environment)—but the form of the piece is brought into being by those interacting with the piece. The interaction takes place at the level of human gesture, without demanding any special technique. There is no beginning or ending to the organization of the sound, no predetermined form. There is only a field of possibilities that emerges from the person, or people, interacting with the piece.

As with much interactive art and aleatoric composition, the composer here has relinquished the traditional role as an authority. However, this particular practice provides a unique perspective on the place of the composer's intention: Certain compositional properties are retained—the choice of predetermined sound material and the spatial layout. As with most audio speakers, any sound material whatsoever can be played through this system. I like to use recordings from Number Stations (intermittent shortwave radio broadcasts believed to be coded spy transmissions), reflecting the fact that the work itself presents a secret code waiting to be revealed by the listener [7].

Figure 4 presents a four-channel system that blends elements of sound installation and visual art to produce an interactive sound environment that can be used to drive a compositional field. Note that the geometry of the electromagnetic field production has been intentionally obscured by artistic concerns. Efficiency and optimization have been thrown out the window. If form follows function here, then the function must be to explore and wander.

GRAPHIC NOTATION

This work could be equally read as a peculiarly active form of visual graphical notation, which allows but does not require sound. Like a score, it can be approached without requiring further action, although the intimation of action remains potent in its markings.

Graphic notation (i.e. the use of non-traditional musical notation) is alive and well and expanding its range to include contemporary composers and artists from many backgrounds [8]. Like most graphic notation, the visual markings in my work are meant to convey directions



Fig. 4. Jess Rowland, *Circuit Drawing*, a four-channel speaker system, copper foil on marbled paper, 24 × 18 inches, 2013. (© Jess Rowland)

for music making that could not be adequately or appropriately transcribed through traditional music notation. But unlike most graphic notation, the relationship between the physical marks and the gesture has been transformed. In this case, the sound is physically *in* the markings. The place of gesture happens *on* the markings. The relation between the physical and the sound has been confounded. One might reasonably ask, then: Is it more appropriate to think of this system of markings as a musical instrument?

In Fig. 5, the size of the image has expanded to that of a body (4 × 2 ft). This piece, *Majikethise*, is a four-channel speaker that allows for interactivity with a sound glove or similar device. It consists of copper foil, as well as magnet wire, recycled plastic industrial circuit sheets used in computer keyboards, aluminum tape and other mixed media on PVC and acetate sheets. Is this piece an audio speaker? Graphic notation? Music composition? Visual art? Musical instrument?

This questioning of boundaries fits into a stream of thought in contemporary music practices. For example, Bigo et al. at the Institut de Recherche et Coordination Acoustique/Musique (IRCAM) developed a paper composition system in which drawing with a specialized pen on notation paper would generate corresponding sounds (played through a computer) [9]. Intended as a compositional tool, it could also be thought of as an instrument itself and evokes the possibility of expanded visual design. Instrument builders are also exploring this blurring of modalities: Adrian Freed, as one example, recently created an instrument with touch sensors attached directly to the diaphragm of the speaker, which plays music in response to those sensors—co-locating the gesture, the tactile experience and the sound production at the same locus [10]. Or consider instruments that play with scale to dissolve spatial, visual and auditory boundaries, such as Ellen Fullman's *Long String Instrument* [11] or Tim Hawkinson's *Uberorgan* [12].



Fig. 5.
Jess Rowland,
***Majikethise*, a**
four-channel
speaker artwork,
copper foil,
magnet wire
and computer
keyboard
circuitry on
PVC, acetate
and paper,
4 × 2 ft, 2013. (©
Jess Rowland)

LOOKING FORWARD, LOOKING BACKWARD

As a blurring of contexts, techniques and modalities, I hope my work raises more questions than it answers. Where is the authorship in this work—at the design or physical medium of the flat speaker? The sound input? The interactivity of the participant or musician? Can contemporary composers be repositioned within this dynamic network so that their place as creators is not compromised but rather given a different perspective?

Moving forward, I would like to scale

these works: What would a room, a building, a garden or a city block be like with this kind of work? Or what of a sparse network of arrays? Most importantly, how can I bring the goal of creating material that literally is sound closer to fruition? This question can be explored in a number of ways—by developing new materials, such as magnetic pastes (perhaps polarized neodymium particles in an acrylic base) or by reconsidering and experimenting with other conductive materials, such as the detritus of industry: cell-phone speakers, thin plastics used in electronics or the substrates for

these materials. I have recently created speakers by embedding these sound materials in sculptural sheets of dried glue, for example.

Our technologies can either isolate us from or bring us closer to meaningful, physical experience of sound. Falling between the cracks of all these artistic labels—art, science, performance, composition—I choose technologies that bring me closer.

Acknowledgments

The author wishes to acknowledge the generous support and guidance of Adrian Freed, Research Director of the Center for New Music and Audio Technology (CNMAT), as well as the kind support of CNMAT.

References

1. Jess Rowland and Adrian Freed, "Flexible Surfaces for Interactive Audio," *Proceedings of the 2012 ACM International Conference on Interactive Tabletops and Surfaces*, Cambridge, MA, November 2012.
2. Paul DeMarinis, *Buried in Noise* (Heidelberg, Germany: Kehrer Verlag, 2011).
3. See an introduction to Christina Kubisch's *Electrical Walks* at <<https://vimeo.com/54846163>>.
4. Hannah Perner-Wilson, "A Kit-of-No-Parts," Master of Science thesis, Media Arts and Sciences, MIT Media Lab, 2011.
5. See <www.sonami.net/works/ladys-glove/>.
6. Marc Leman, *Embodied Music Cognition and Media- tion Technology* (Cambridge, MA: MIT Press, 2007).
7. An on-line demo is available at <www.jessrowland.com/art/electronicpaper-speakers/interactivity/>.
8. Theresa Sauer, *Notations 21* (New York: Mark Batty, 2009).
9. Louis Bigo, Jérémie Garcia, Antoine Spicher and Wendy Mackay, "PAPERONNETZ: Music Composition with Interactive Paper," *Proceedings of the 9th Conference on Sound and Music Computing*, Copenhagen, July 2012.
10. Jess Rowland and Adrian Freed, "Colocated Surface Sound Interaction," *Proceedings CHI '13 Extended Abstracts on Human Factors in Computing Systems*, Paris, France (May 2013).
11. See <www.ellenfullman.com/Biography1.html>. See also Ellen Fullman, "A Compositional Approach Derived from Material and Ephemeral Elements," *Leonardo Music Journal* **22** (2012).
12. See <www.oddmusic.com/gallery/om32290.html>.

Manuscript received 2 January 2013.

Jess Rowland is an artist and composer affiliated with the Center for New Music and Audio Technology at UC Berkeley. She is a recent graduate of the University of California Berkeley Art Practice MFA program with a certificate in New Media.