Flexible Surfaces for Interactive Audio

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Abstract
We present here flat flexible audio speaker surface arrays, which are transparent, formed to various environments, and allow for user interaction. These speaker arrays provide an alternative to traditional models of sound reproduction, which often involve discreet point source systems and bulky hardware passively received by the user. The surface array system opens up new possibilities for acoustic spaces, creativity, and sound interactivity

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Introduction
Planar speaker technology has been well-known and studied for many years, though such systems are generally built on the same design concerns as traditional loudspeaker, and use bulky magnets (1, 2). However, it is possible to build a sound system from an alternative aesthetic that is applied only on the surface, distributed, stochastic, continuous, multimodal, with potentially unlimited channels and allows for new practical and artistic possibilities. We have developed a flat flexible speaker array system that was motivated by these interests. The surface depth of our flexible array is reduced from centimeters (in traditional planar speakers) to up to less than a millimeter, and the surface for these speaker arrays are potentially unlimited by curvature or folding. Furthermore, our speaker array is both more lightweight and cost-effective than standard loudspeaker designs. These speakers afford creative and practical uses, interactions, and sound spaces that are not available to standard speaker design.

System Design

Our system of flexible audio driver arrays is based on conductive materials suitable for flexion and flat surfaces, such as conductive inks and thin foils. Surface substrates consist of flexible magnetic strips, paper, foams, plastics such as clear acetate, and other lightweight flat surfaces which allow small rare earth magnets of 1 mm depth, or magnetic particles, to be attached or embedded in the material. Our 2-D voice coils are made from machine-cut copper sheets (.001” thick), or by inkjet printing and electroless copper plating onto flat surfaces. Figure 1 shows a typical array system using copper foil adhered to paper.

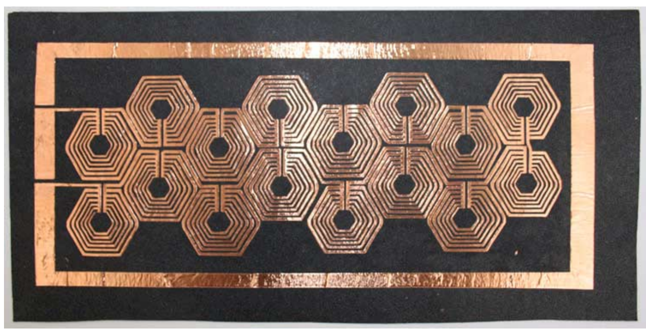

Figure 1. A flat speaker array of copper foil on paper

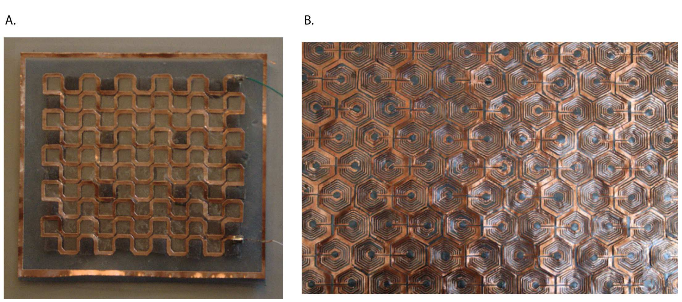

Figure 2. Two flat speakers designs using maximal tiling A. Square speaker. B. Hexagram speaker

The effectiveness of these surface speaker designs relies on maximizing the potential magnetic field and magnetic flux at the level of the surface itself. For maximum efficiency on the surface, the interaction of the electromagnetic field and the permanent magnetic field is strongest at the boundary of the magnet and drops off rapidly thereafter. Therefore, maximizing this boundary across the sheet or surface is optimal for the strongest audio response. We used regular tilings, such as these ones using squares, or hexagrams, to create a dense sheet of copper foil arrays on a clear acetate backing (Figure 2).

Geometric patterns which maximize packing, such as regular tilings and Archmidean tilings, and –at a theoretical ultrafine resolution - space-filling curves (e.g. the Sierpinski Curve), can be utilized to best drive this response.

Applications

In addition to performing the function of a diffuse and distributed audio loudspeaker system, these arrays allow for interactivity through the use of magnetic gloves, and provide for multiple configurations of multichannel input and output.

Figure 3. A Sound Glove with Magnet Attached

By mounting the magnets in gloves worn by the listener, an active experience is created in which gestures control sounds from the speaker array. These “sound gloves” consist of every-day gloves with a permanent neodymium rare-earth magnet attached (Figure 3). Since there is no wiring or electrical system involved in the gloves themselves, users have the full use of movement freedom to explore the arrays. Sound is generated in proportion to the proximity of the user’s hand to the array. Since there is no computation, data measurement, or information control involved in this process, the glove provides a natural and unmediated alternative to the same functionality available in wireless proximity sensors generating audio feedback. Arrays can also guide users to interaction points where the electromagnetic field is maximized, opening up possibilities for haptic, tactile, and audio feedback from the glove.

Figure 4. 4-Channel Speaker Utilizing Artistic Possibilities of the Surface

Figure 5. "Uncle Bill". A one-channel flat speaker on flexible magnetic sheeting.

Multiple channels can be incorporated into the system with user interaction. Figure 4 presents a four-channel system that blends elements of sound installation and visual art to produce an interactive sound environment.

Note that the geometry of the electromagnetic field production been intentionally obscured by artistic concerns. With these 2-d speaker arrays, artistic and design possibilities open up for sound art, sound installation, patterning and graphic design, which are not part of standard sound reproduction aesthetics.

It is also possible to explore photographic material as a basis for flat audio circuitry design. Using commonly available rubberized ferrite magnetic sheets with a circuitry design maximized to respond to the vagaries of the anisotropic ferrite deposition on the flexible magnetic sheet, photographic half-tone strategies can be employed on the surface, such as in this speaker/image of William Burroughs (Figure 5).

Discussion

Flexible audio speaker arrays are a useful alternative to standard models of loudspeaker design. Because of their flexibility, ability to form, and wrap, new multimodal and interactive possibilities emerge. Sound surfaces allow for haptic and tactile feedback, as well as auditory feedback, without requiring direct contact.

Audio speaker design has been used as part of auditory aesthetics at least as early as the Ondes Martinot, which utilized multiple speaker outputs to adjust timbre and sound quality (3). More recently, sound artists have explored manipulated traditional speakers as part of their practice (4, 5).

Our current work shows that visual aesthetics and sound art can also be explored on surfaces in a way that 3D speaker design does not allow. DIY paper speaker design has been pioneered by Hannah Perner-Wilson (6) and Marcelo Coehlo (7). In the same spirit as their work, the technology explored here can be designed and implemented by anyone with some basic supplies available at their local art store, rather than requiring industrial machinery.

This rethinking of the fundamental properties of audio circuitry design shows alternative ways to imagine our relation to sound. Explorations of circuitry geometries can open up new possibilities for sound applications to be embedded in real environments and embodied in our interactivity.

Acknowledgements

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