# Alternative Voices for Electronic Sound:
*Spherical Speakers and Sensor-Speaker Arrays (SenSAs)*

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**Abstract**

We describe several recent applications of spherical speakers (multi-channel, outward-radiating geodesic speaker arrays) and Sensor-Speaker-Arrays (SenSAs: combinations of various sensor devices with spherical speaker arrays). We discuss the design and construction of these systems, and, more generally, the new "voices" they give to electronic sound.

## Introduction

Arrays of widely spaced mono-directional loudspeakers (P.A.-style stereo configurations or "outside-in" surround-sound systems) have long provided the dominant paradigms for electronic sound diffusion. So prevalent are these models that alternatives have largely been ignored and electronic sound, regardless of musical aesthetic, has come to be inseparably associated with single-channel speakers (often in relatively high-volume contexts), or headphones. We recognize the value of these familiar paradigms, but believe that electronic sound can and should have many alternative, idiosyncratic voices. Through the design and construction of unique sound diffusion structures, we can reinvent the nature of electronic sound; when allied with new sensor technologies, these structures offer alternative modes of interaction with techniques of sonic computation

This paper describes several recent applications of spherical speakers (multi-channel, outward-radiating geodesic speaker arrays) and Sensor-Speaker-Arrays (SenSAs: combinations of various sensor devices with outward-radiating multi-channel speaker arrays). Spherical speakers have long been applied in the study the acoustic qualities of performance spaces (see, for instance, Hidaka and Beranek, 2000) and instruments (Caussé *et. al.,* 1992; Roads, 1996; and Wessel, 1991). More recently, building on previous studies of the directional radiative properties of acoustic instruments (the NBody Project; Cook and Trueman, 1999), they have been used in performance to reproduce some of the diffusion characteristics of conventional acoustic instruments; spherical speakers engage the reverberant qualities of their performance spaces and allow electronic and acoustic instruments to blend readily.

After custom-building several spherical speakers by hand, we began working with the U.S. Enclosure Company to produce over a dozen spherical speakers of varying sizes ranging from 8-inch to 14-inch. We will detail their use in the performance and recording of two works by composer Steven Mackey: a concerto combining electric guitar and digital signal processing with full orchestra, and a composition for string quartet and live-electronics/electric guitar. The electronic improvisation ensemble "interface" (Bahn and Trueman) has integrated a family of these spherical speakers into their standard set-up, completely replacing their previous P.A. diffusion model; as we discuss, this has encouraged us to substantially reinvent our approach to the performance of live interactive computer-music.

This presentation introduces a large new 22-inch diameter SenSA (Bubba) motivated by the first SenSA, the Bowed-Sensor-Speaker-Array (BoSSA; Trueman and Cook, 1999). The two SenSAs have been used together in performance to realize a new approach to electronic chamber-music. BoSSA has also motivated several new works for interactive dance performance systems and SenSA. Finally, we are exploring the use of spherical speakers and SenSAs in installation art, using the directional capabilities to create more compelling sonic experiences in open and closed spaces. We describe the design and construction of these systems, and, more generally, the new "voices" they give to electronic sound.

## Electronic Sound in Conventional Acoustic Ensembles

Combining acoustic instruments with electronic sound is a notoriously difficult problem. By subtly amplifying the acoustic instruments and adding a judicious amount of artificial reverb, we can often succeed in bringing their sound into the electronic realm, creating a virtual electronic space. While good for many applications, this approach usually has the effect of negating the natural acoustic qualities of performance spaces and can make it difficult to localize the acoustic sources ("I can't tell who is playing what," is a common complaint—this may be desirable, but should not be inevitable). As the size of the acoustic ensemble grows (especially to orchestral proportions), it becomes increasingly difficult to absorb it into the virtual electronic space—acoustic and electronic sources begin to separate, like oil and water. Finally, this approach presumes that electronic sound is intended exclusively for performance (projecting outwards), and is not a solution if we are interested in making a kind of electronic chamber music, where the social/acoustic context of music making is of primary importance (and performance secondary).

From our work studying the spatial radiative timbral qualities of acoustic instruments (NBody), we have found that spherical speaker arrays offer a compelling alternative. Since they radiate sound spherically, these speakers engage the reverberant qualities of performance spaces similarly to acoustic instruments. They also localize well, and provide an approach that does not assume performance (they are remarkably successful in small, chamber music contexts). With this approach, we invert the previously described technique by bringing the electronic sound into the acoustic space.

Figure 1: an early spherical speaker with electric violin

Our first significant application of spherical speakers in a musical context is a set a of duos for 6-string solid-body electric violin and Classical guitar (by Trueman). In this case, rather than amplifying the guitar to match the electric violin, the electric violin becomes "acoustic" and matches the guitar, in both level and reverberation. These duos are heavily influenced, both musically and socially, by Traditional ("Folk") music, where performance is not necessarily separated from the activity of music making and a divide between performer and listener is not obvious (as in some traditional dance music).

These duos were followed by a chamber work (*Machine Language*, also by Trueman) for electric violin with acoustic violin, cello, and percussion. One of the intentions of the piece was to explore how we could expand the sonic palette of a conventional chamber ensemble with an electronic instrument without destroying its rich acoustic surface. We were also hoping to maintain the familiar modes of interaction between chamber musicians, where sound localization is important and music-making as *activity* (apart from performance) is (or was) of primary interest. The success of this endeavor has encouraged us to pursue these possibilities further and has inspired other composer/performers to adopt spherical speaker arrays for their own compositions.

One example is the composer and electric guitarist Steven Mackey. Mackey's *Troubadour Songs* (for string quartet and electric guitar), though successful, have proven difficult for obvious reasons—blending the electric guitar and string timbres while maintaining comparable levels is difficult. Through the use of a new spherical speaker, Mackey has been able to address this problem in both performance and recording; in a recent session, the pieces were recorded in a large hall with open-air microphone placement (conventional for string quartet recordings) and close-mic'ing of the guitar amplifier was unnecessary.

This new "voice" for the electric guitar figured heavily in Mackey's composition of a new concerto *(Tuck and Roll)* for electric guitar and orchestra, premiered in April 2000. Mackey composed the work with these new speakers in mind, and conceived of the electric guitar as a member of the orchestra. He adjusted equalization settings, quantities and qualities of distortion, chorus and other effects to create a unique new orchestral voice that could match the various instruments of the orchestra in different combinations.

Figure 2: stage setup for Mackey's *Tuck and Roll.* Arrows indicate locations of spheres.

Mackey's sphere (14-inch diameter, with twelve 4-inch coaxial drivers distributed symmetrically over its surface), is stereo (a plane divides the interior of the sphere, and the two halves are wired separately). With the orchestra, he used two spheres, arranged as in Figure 2. The sphere next to Mackey was the primary sphere, the second providing slightly more volume to match the orchestra. Both were oriented so their two channels could be adjusted "front and back;" the orchestral, "back"-side was initially set rather loud, while the orchestra learned the piece, but as they became more familiar with it, the back-levels were attenuated.

Mackey found that adjusting the relative gain of the front and rear hemispheres had a significant effect on the orchestra's performance; initially, with the back-side rather loud, the orchestra overplayed, trying to match the level of the soloist—after softening the back-side, the orchestra played more sensitively, which afforded the soloist (Mackey) a greater dynamic range. In either case, the spatial radiative qualities of the front-side kept the electric guitar in the natural acoustic space, and negated any need for conventional P.A.-style amplification.

Audience feedback consistently indicated that the acoustic effect that Mackey sought—a convincing blend of electric guitar with orchestra—was successful; listeners and orchestra members felt that the guitar "blended effortlessly," that it seemed to "belong." Ironically, this was initially troublesome to some listeners (and the conductor) whose conception of the electric guitar as musical icon—loud, macho, aggressive, epitomized by the Marshall Stack or

Fender Twin amplifiers—was quite different than Mackey's approach. For these listeners, there was a kind of cognitive dissonance created by their expectations of the "electric guitar" and Mackey's new instrument. For most, however (including the conductor, Michael Tilson Thomas), this frustration eventually gave way as the instrument and composition asserted their own musical personalities.

**Making Electronic Ensembles More Intimate**

The electronic improvisation duo "interface" (Bahn and Trueman) began as a purely acoustic duo, improvising informally in living rooms, recording studios and other small spaces. As we integrated electronics and computation into our improvisations, our conventional sound system grew, eventually completely obscuring our acoustic beginnings. In our most recent season, we replaced our P.A.-style system with a set of five spherical speaker arrays of various sizes, including two 14-inch spheres, a 12-inch sphere, an enormous 22-inch sphere (Bubba; described further below), and an 8-inch tweeter-ball. These speakers, strewn about the stage in various configurations, function much like instrumental sources and create a sound field somewhat similar to a conventional chamber ensemble (see Figure 3). The spheres localize our sounds, providing distinct points on stage for listeners and performers to grasp, yet also fill spaces and encourage listeners to walk among us; the typical plane of separation created by stage and P.A. system is non-existent. We find that this sound system drastically affects the way we play our electronic instruments, encouraging us to play softly and explore spare textures. It also feels familiar, reminding us (distantly) of our earlier, more "acoustic" improvisations.

Figure 3: Trueman on stage with "interface"

Bahn has used a hybrid system in performance, combining spheres with conventional speakers. Four stereo spheres are set amongst live performers amplifying and processing their sound. Most often, the sound sent to the spheres has a consistent routing, giving the spheres a particular sonic "identity" on stage and within the ensemble. As with all applications discussed in this presentation, this integration of natural and electronic sounds can be strikingly natural and effective. Signal processing representing impossible acoustic situations, extreme delay, reverb or other effects, can then be cast into a conventional sound system at the back or sides of the performance space. The hybrid approach allows manipulation of both individual points of sound within natural sonic space, and the altered perception of space provided by conventional sound systems.

**Reorienting our Relationship with Electronic Sound**

Given the instrumental qualities of spherical speaker arrays, it makes sense to actually imagine them as instruments. We recently described a new instrument—the Bowed-Sensor-Speaker-Array—that combines a 12-channel spherical speaker array with a variety of sensors inspired by the physical interface of the violin. This instrument, which was our first Sensor-Speaker-Array (SenSA), has been used in performance many times and is undergoing constant refinement (*BoSSA Nova* is near completion). As we argued, BoSSA suggested the possibility of a new kind of electronic chamber music. With this in mind, Bahn constructed an enormous 22-inch 12-channel spherical speaker (Bubba) and a matching (much smaller) sensor-ball (the Bubba-Ball) to "play" Bubba (see Figure 4).

Figure 4: Bahn, "Bubba" and the "Bubba-Ball"

In combination, BoSSA and Bubba form a compelling, if somewhat bizarre ensemble. Both SenSAs reorient our relationship with electronic sound and convey a strong sense of physicality in performance. No longer detached from the sound source, we often feel as though we hold the sound in our hands. The experience is similar to performing with an acoustic instrument and the effort required can be equally exhausting. Given the lack of any direct acoustic sound source, we have freedom to redefine the mappings from sensor to synthesis/signal processing parameter on the fly, which in turn transforms our physical relationship with the instrument; in a sense, instrument design itself becomes an aspect of performance (we don't have to go back to the shop to alter the "feel" of our instruments; we do it in realtime).

**Interdisciplinary Applications**

*Streams* is an interactive sonic landscape formed (by Bahn) in collaboration with dancer Tomie Hahn. Custom sensors capture the tilt and movement of her arms and record pressure of touch on a small resistor in her palm. A MIDI radio transmitter sends this information back to a computer-performance system where it is mapped into interactive synthesis and signal processing designs within the MAX/MSP environment. The sonic landscape is displayed using three spherical speaker arrays placed behind her, to her left, and to her right. Discreet aspects of the composition are uniformly cast into unique speaker arrays forming individual, physically locatable "identities" within the sonic design and installation of a performance. Signal processing algorithms—granular synthesis, delay loops and reverberation—can be activated by the dancer during a performance. These altered sounds are cast into spatialization algorithms that pan and distribute sonic grains between spheres.

There is no pre-set structure or duration to a performance of *Streams*. The intention of the composition is to give the dancer improvisational freedom and control over the micro and macro elements of the sonic structure. A performance is then a physical exploration of the sound-space. The Sensor/Speaker array concept, sensors recording large body movements and controlling multiple sonic identities on stage, makes sound a very tangible theatrical element in solo movement performances while creating an intimate natural sonic space.

We have also used hemispherical speaker arrays for interactive sound sculptures and installations. *[PariSphere 1]: 31m* was designed (by Cook) as a coffee table commentary on alienation and media globalization, "...with 500 channels of satellite TV, we still feel alone..." The piece encourages us to take comfort in the audio-only village available near the 9.4 MHz band. Movement around the hemisphere causes the internal short-wave tuner to seek stations and display them randomly in the six speakers on the surface of the hemisphere. See Figure 5.

Figure 5: *[PariSphere 1]*

*[PariSphere 2]* (also by Cook) fills a hallway with the sounds of children using two hemispherical speakers located on the floor, one at each end of the hall. Movement through the hall causes the sounds to play and be spatialized in the 2x6 total speakers. Sound playback is from a 'hacked' MPEG-3 player controlled by a micro-processor responding to input from motion sensors located in each hemisphere.

## Conclusions and Future Work

Spherical speakers provide a compelling new "voice" for electronic sound, one that is particularly compatible with acoustic instruments and well suited for intimate spaces. SenSAs further enhance these qualities and create a new class of electronic instrument. This work also suggests a more general approach towards working with electronic sound and human-computer interfacing, one which emphasizes outward, multi-directional (though not necessarily symmetrical) diffusion with proximal, physically motivated sensor structures. In the future, we plan to pursue some of these possibilities, including designs that are more idiosyncratic, asymmetrical, yet retain some of the diffusion qualities of spherical speakers. As with traditional instruments, these structures have unique acoustic characteristics that may be exploited musically, diversifying the voices of electronic sound. Further dance pieces, a multi-channel sonic-sensor sculpture, and new SenSAs are currently in the early stages of design or construction.

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