# Loudspeaker array as a musical composition genre

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**Abstract**

A fixed array of loudspeakers can be used as a proprietary format for electronic music composition, leading to a fixed genre of work. The author will describe his experiences using a 6-channel array of full-range loudspeakers, describing the compositional principles he has employed, including issues of source localization, ambient and reverberant fields, available bandwidth and sound pressure levels. Spatial relationships, musical issues and problems and related concerns will all be discussed.

## Background

### Electronic Music Composition

Electronic music composition has been with us since before World War II. The processes and techniques have concentrated on the generation of new instruments (mostly syntheisizers), new modalities of considering the audio signal and new ways of thinking about the composer/machine/performance interface. In the evolution of electronic music, comparatively little attention has been paid to the loudspeaker – it has been treated as a generic black box, a generic portal to convert the composer's creative efforts and electronic realizations into sound for the listener.

### Loudspeaker As Musical Instrument

In a previous paper for the ASA[1], I described the loudspeaker as a musical instrument, and described the ways it fits into the family of musical instruments, including a consideration of the genre of music called loudspeaker music. I suggested that when we view it in this light, and consider loudspeaker music as transcriptions from other musical media, that we can see more clearly through some of the puzzlements and confusions that confound us in loudspeaker design and usage. However, in that paper I did not consider the use of an array of loudspeakers as a specific musical instrument, an instrument essentially without precedent, an instrument that offers us some fresh ways to think about and approach the creation of music.

### The BeoLab 5 Loudspeaker

In a companion paper[2], I described a new loudspeaker, the BeoLab 5 by Bang & Olufsen, that attempts to resolve a number of loudspeaker/room/listener interface problems. I suggested that such a loudspeaker is a powerful enabling device for such loudspeaker


 

music applications, due to its unique combination of full-bandwidth dispersion, room adaptation, amplitude range and timbral neutrality and flexibility.

The development of the BeoLab 5 was, for me, the culmination of a twenty-year effort to obtain a loudspeaker array that functioned in inherently musical ways. I have come to believe that the use of such a loudspeaker is essential for high-quality realizations of electronic music, and that without such loudspeakers, such music is seriously degraded and marginalized in ways that simple recordings (transcriptions) of traditional music avoid, due to the willing suspension of disbelief that attends such traditional musical playback experiences.

At the present time, I am using an array of six BeoLab 5 loudspeakers in a proprietary array as a fixed instrument for which I am composing a body of music. In this paper, I will discuss that effort.

## Composing For Loudspeakers

### Musical Assumptions

Music for loudspeakers does not, necessarily, require the composition of a notated score. Further, normal notational elements of music (i.e. a specification that an oboe should play a C# mezzo forte and staccato on the 2nd beat of measure 27) do not exist. The palette for loudspeaker sound is in fact the range of audible raw sound materials, a range of choice that is often so large as to be daunting. Audio signals are created via the use of synthesizing devices, the manipulations of recordings and elaborate signal processing chains.

The primary compositional musical assumption has been that "anything goes," and that non-referential, non-pitched and/or "original" sounds are desirable. Original juxtapositions of traditional materials, transmuted materials and original materials are also generally held to be highly desirable.

### Compositional Traditions

Compositional traditions for electronic music have in many respects mirrored those of traditional composition, with the observation that the act of composing electronic music has considerably more in common with the act of sculpting than does the more traditional composition process. The electronic composer creates, shapes and assembles "sounds" which are then "played" for the listener by a mechanical medium. In general, electronic music composition has not led to new musical forms that are inherent to the medium, although it is particularly suitable to a musical character I call "machine music," the audible working out of mechanical processes. Much music composed in the 20th Century for all media has been "machine music,' including a great deal of dance music.

To date, composers have devoted themselves primarily to the sound generating processes, the synthesizers, the tape recorders and the signal processors they find of interest. They have used these to create more or less "traditional" works, i.e. works of typical length and

scale to be played either by conventional commercial loudspeaker arrays (i.e. stereo) or in "installations" where speakers are distributed throughout a space, often by a sound contractor and usually not as part of the compositional design. An interesting variant of this is called a "diffusion," wherein a stereophonic electronic music composition is adapted for playback by a complex multichannel array of loudspeakers.

The point about all this is that the loudspeakers and their configuration have not generally been treated is organic primary elements in the compositional process, nor have the compositions generally focused on what is idiomatic for loudspeakers.

### Differences between Loudspeaker Performance and Live Performance

In my earlier paper, I made the following observations about the relationship between loudspeaker music and live performed music.

Live music is public and usually occurs in crowded venues, while loudspeaker music is generally performed in private.

- Live music is highly social and ritualized, while loudspeaker music is casual, ubiquitous and often extremely private and intimate.

- Live music has a strong emotional interaction between listeners and performers, while loudspeaker music has no interaction at all between listeners and performers.

- Live music is mostly limited by human capabilities for performance (except when sound reinforcement is used), while loudspeaker music is not constrained by human performance limitations.

- Live music is a one-time event not under the listener's control, while loudspeaker music is under the direct control of the listener, who can vary it's spectrum and level at will. It can be played on demand, stopped, restarted and repeated exactly, ad infinitum.

- Loudspeakers can play indefinitely, at any reasonable level. Loudspeakers can play higher, lower, louder, softer, faster and slower than any other musical instruments.

These insights suggest the possibility of new musical genres and forms, disconnected from the constraints and benefits of the concert experience.

### The Curious Case of Stereophony

Also in my earlier paper, I proposed one possible characterization of the loudspeaker as a "Universal Sound Generator." Interestingly, due to the unique quality of loudspeakers of being able to operate in phase-locked synchronous arrays, I also noted that they can function as "Universal Sound Environment Generators." This remarkable quality is, of course, the foundation for stereophony.

It has been my experience that we casually accept the powerful sensory quality of stereophony without much question about its actual mechanism or meaning for humans,


 

and that we have devoted little compositional time and effort to a consideration of the sensory implications of such phase-locked synchrony and arrays.

Nonetheless, one of the most powerful and unique aspects of loudspeaker music is that it can be used to generate unique sensory environments (and movements through such environments). To date, such qualities have not been exploited much beyond what is easily possible in commercial stereophonic arrays.

## Creating A Loudspeaker Array

The loudspeaker array I have created is based on some commercial antecedents. I earn much of my living producing and mastering commercial recordings for others, as well as teaching and writing about it, and so I need and use such commercial arrays on a daily basis.

### Precedents:

When I first began to work with synthesizers (ca. 1968), I had no knowledge or experience regarding the historical traditions underlying loudspeaker music or any knowledge of the craft of making recordings. I began with stereo because that was what was available. I soon began to work with a 4-track recorder and almost immediately went to a quadraphonic array. At the same time, I began recording others professionally, and devoted a good deal of my efforts to developing my craft to serve them. I had no quadraphonic clients, so whatever work I did in quadraphony was entirely for my own experimentation and interest.

I quickly discovered that I could, both by accident and intentionally, generate surprisingly beautiful sounds and sensory environments using a quadraphonic array, sounds that I could not begin to approach in stereo.

At the same time, I began to notice that the quality of loudspeaker performance was directly related to the quality of loudspeakers. Further, I noticed that I did not have the technical capacity to realize and control the musical compositional processes that I desired to work with.

For a significant period of time (ca. 1975 to 2000) I devoted myself to research and development of loudspeakers as an essential part of developing my craft as a composer, while also waiting for the technical capability that I felt I needed to become available and affordable.

### The Five-Channel Array

In the mid 1990s, I built a post-production studio for my own use in my home that was to be used for both commercial work in stereo and also for my own surround recording. By that time, a 5-channel home theatre playback modality was in place that I believed I could use viably for my compositional efforts. I hoped that such a configuration would give me a release and distribution medium for my music.

### A Sixth Channel: The Need for Verticality

During a visit to Paris in 1995, I was strongly affectedN by the vertical sensory quality of many of Claude Monet's large Water Lily paintings on exhibition at the Musee Marmottan. It seemed to me that it might be very important to invoke the sense of verticality I was so moved by in those paintings.

Consequently, in June, 1995, I installed a full range ceiling speaker in my studio to go with my five-channel horizontal array. Although I was prepared for this to be a wasted effort, I was pleased to find that it yielded some wonderful ambiences. At the same time, I discovered several recording engineers that were capturing vertical information as part of surround recordings that they were making. When I auditioned their work I became convinced that the vertical channel was an extremely important ingredient in creating a viable multichannel sound field.

At that time, I fixed my loudspeaker array to include five horizontal and one vertical channel, all full-range and all using wide-dispersing high-frequency acoustic lenses that I shared in inventing.[3] For commercial viability, I fixed my surround array to have speakers at 0°, 35°, 135°, 225° and 325°, plus the overhead speaker at approximately the same distance (9') and approximately 15° forward of vertical.

Since that time, I have also experimented with having the horizontal array as a pentagon (0°, 72°, 144°, 216° and 288°) and find that it is generally preferable (it also works wonderfully for 3-channel stereo!). However, due to my commercial work, I have retained the conventional alignment. It is my plan to use the pentagon for any gallery presentations.

## Classes of Musical Source Sounds and Environments:

### The Monophonic Source

The monophonic signal is well-known and understood. It consists of a single signal trace. It appears unequivocally at the emitting loudspeaker. Any reverberant or ambience traces embedded in the signal appear as artificial, and do not contribute to the ambient sense of the array.

When sent equally to two identical loudspeakers, the monophonic source appears as a phantom image between them, subject to the rules for phantom images.

### The stereophonic source

A stereophonic source consists of two partially correlated signals. Subject to the rules for phantom images and phantom reverberance, it appears as a phantom image between the two loudspeakers, with a phantom ambient or reverberant field stretching between (and sometimes outside of) the stereophonic array. For a signal pair to be sufficiently correlated to qualify as stereo, the amplitude difference between the signal artifacts on the

channel pair needs to be less than 8 dB and the time difference needs to be less than approximately 40 ms.

### The 6- iteration source

A 6-channel source is conceptually similar to the Ambisonic B-format signal. It includes a correlated array of artifacts that both serve to localize a single phantom image or images somewhere on or beyond the surface of the sound field, as well as to carry the enveloping ambience and/or reverberance that accompany such an artifiact.

### Complex 6-channel voice arrays

A complex 6-channel voice array includes both a group of related sources (which are usually monophonic) that have a specific musical function (a hocket, an echo-loop, a chord or cluster, etc.) plus (usually) an associated ambience and or reverberance.

### Ambience & Reverberance in 6 channels

At present, surround reverberators are configured for conventional surround topographies, and include no provision for height channels. My solution has been to appropriate the center channel for a height channel and reconfigure the reverb (I am using a Lexicon 960) so that the center channel is picking up in the center toward the rear. I find this works in a generally convincing way.

Another reverberant possibilitiy exists: a reverberant environment that includes no source sound, and either decays or grows (if the reverb is reversed) independently of such ommitted source sounds. There is no acoustical equivalent to this behavior. Surprisingly, it is generally quite beautiful and moving, a very powerful musical gesture and condition.

### Additive Synthesis, Subtractive Synthesis and Samples

The creation of source signals can be done a variety of ways. I have used conventional synthesizers, “found” recorded source beds, and manually generated tones. I am looking forward to the use of high quality “orchestral source” samples, but am unsure of how such cognitively association-loaded sources will fit into my sonic landscape. At present, I am working almost exclusively with sine, square and sawtooth waves, with white and pink noise, and with reverberance in a kind of additive synthesis realm.

### Intonation, Beating and Fine Tuning Issues

An extraordinarily interesting and powerful effect unique to loudspeaker arrays (and synthesizers!) has to do with the use of precisely tuned interval ratios. It is now technically trivial to tune to precisions of .001 Hz (one complete phase shift every 17 minutes). This leads to the generation of “beat-free” chords that are unprecedented in musical performance, with an entirely different sonic character and emotional affect. Distributing an absolutely beat-free 6 part open-voiced C-major chord among 6 speakers, for instance, yields some remarkable sensations, including a quality of sonic envelopment

that is quite unique, as well as a striking and almost liquid Doppler shift that accompanies any and all motions of the listener, leading to a swimming sense of immersion within the chord.

## Compositional Strategies

The following processes are natural and idiomatic for loudspeakers and the production mechanisms that support them.

### Machine Music

Machine music involves the working out of rhythmic and/or mechanical patterns and processes. The mechanical nature of our synthesis and various DAW-related music production systems seem extremely well-suited to generating such music. The ease with which our productions systems permits the effortless generation and realization of complex polyrhythmic patterns and the working out of such motor patterns make them well suited to create process that have fascinated many 20th Century composers.

### Extended Growth and Decay Processes

Loudspeakers and DAWs effortlessly cope with extended sequences of crescendos and diminuendos, which can easily take an hour, if desired. These structural sizes are beyond the capability of live performers or the constraints of the live performance venue.

### Hocketing

Hockets (melodic sequences that bounce between various performers) are fascinating and delightful music behaviors. It is extremely easy to generate hockets that exist between loudspeakers (channels). The spatial interactions are extremely interesting. Rhythmic interactions subtly change as the listener changes position between the speakers.

### Iterative Loops

The idiomatic tape echo and related multi-channel tape-echo loops that change over time are absolutely generic to loudspeaker music to the point of having become a cliché. Such slowly evolving loops present powerful opportunities for composers to create organically changing musical landscapes and sonic voyages.

### Canons

Literal canons are simply realized with cut and paste editing. More complex imitative canons are comparatively easily generated and realized, including canons of diminution and augmentation, as well as canons at various intervals.

## Musical Motion

### Simple Panning

Amplitude panning is  of course absolutely generic.  It works extremely well for rapid pans, and moderately well for slow pans.

### Time Domain Panning

Panning in the time domain can also be done through the introduction of microscopic pitch/time shifts of one of an identical pair of tracks.  Such pans have considerably more interest than amplitude-based pans.

### Complex Multichannel Motions and Migrations, including Doppler Shifts

Panning that involves a complex array of channels, including reverberation, can be quite complex.  Done well, such pans can be stunning, especially if a pitch shift (mimicking Doppler Shift) is involved.  Particularly powerful are front to rear Doppler pans (through the overhead speaker), especially  when the reverberance reverses (so that primary reverberance starts in the rear for front-based sounds and pans to the front as the front-based sounds pan to the rear.

### A Hypothetical "Star-field" Pass-through Algorithm

I have long wished to have an algorithm that causes signals introduced on a continuing real-time basis into the algorithm to migrate smoothly from front to rear, including Doppler shift, with various sideways displacements and fading away behind us (equivalent to the sort of screen saver that gives us the illusion of going through a star field).

## Vertical Layering

A single vertical speaker actually allows us to "pull" a signal "upward" in apparent elevation (through a ratio of horizontal-to-vertical amplitude distribution).  This permits us to have sounds overhead, sounds at the horizon and sounds in between as distinct strata.  These seem to have different emotional meanings.  Further, we can have reverb high or low, and we can equalize reverb differently at various heights, for instance making the overhead reverberation quite dark and foreboding with the horizon reverb quite light and airy, or vice versa.

## Production Tools

### A Digital Audio Workstation

I use Pro Tools, which appears to be almost ideal for this sort of work.  Rhythms are extremely easily handled in Grid mode and the effortless multiplicity of channels make it

close to ideal. The biggest flaw I have found is Pro Tools' inability to allow the user to easily modify the clock rate for a given signal to create slow and well-controlled glissandi, beat-rate changes and the like.

A Surround Reverberator

I have found the Lexicon 960 surround reverberator to be a close-to-ideal spatial generator. When utilized in conjunction with automated reverb send levels and panning, and appropriate automation of reverb spectrum, this reverb has proved to me to be invaluable in obtaining the textures I desire.

A synthesizer

Interestingly, I find the use of a synthesizer (especially with stock patches) to be less and less important. Mostly, I generate libraries of carefully tuned sine, square and sawtooth waves and work with these as primary sound materials via cut and paste in Pro Tools. However, I expect to move back toward synthesizers in the future as time and finances permit.

## Some Aesthetic Questions

### Issues of Scale

How long is too long? How short is too short? Too high? Too low? Too loud? Too soft? The normal concert constraints are gone, and it is easy to imagine pieces that run for multiple hours, with improbable spectra and amplitudes, all of which invoke strong emotional responses (some, of course, averse). At present I find a comfortable length to be somewhat less than an hour. Due to the private and intimate nature of loudspeaker listening, "ambient" textures that evolve over tens of minutes seem entirely reasonable for comfortable listening. Further, dynamic ranges can range from almost as loud as a symphony orchestra (ca. 120 dBC SPL) to much, much softer than an orchestra can play. One wonderful and idiomatic loudspeaker gesture is the slow fade that finally merges with room noise and then fades from sensory awareness as it continues to fade out below room noise. This may take five to ten minutes, and it is quite mesmerizing for listeners.

### Relation to traditional performance

This sort of idiomatic loudspeaker music has little relation to the kind of ceremonial tension inherent in live performance. The lack of psychological interaction between performer and listener adds to the cool affect of loudspeaker music. Loudspeaker music seems much more suited to be "organic," "mechanical," "related to nature," "patterned" and "intimate," as well as "cosmic," "alien" and "otherworldly." It does not stand in well for the emotional intensity from a passionate live performance. It is, on almost all fronts, an extremely different sort of artistic experience.

### The Failure of the Willing Suspension of Disbelief

One irony of this music is that it suffers badly when played back over poor systems (which, sadly, has been the fate of virtually all electronic music distributed via records and CDs). We use the willing suspension of disbelief to permit ourselves to invest in the musical quality and intensity of recordings of traditional performances. That suspension allows us to forgive a lot, much more than we usually recognize.

Pure electronic loudspeaker music does not refer to traditional performance, and therefore, ubfortunately, there is no disbelief to suspend. As a result, our perception is much more literal, and sonic failures are perceived as performance and/or compositional defects. This is particularly true in terms of distortion components and the loss of multichannel low frequencies (particularly when low frequency content is summed to a single subwoofer, which destroys a great deal of envelopment).

The implication of this is quite important for such music. It means that the music cannot reasonably be distributed via stereo or multi-channel CD to any playback system, but is in fact dependent almost entirely on the quality and integrity of the loudspeaker system and its installation. Transcription to lesser systems doesn't work. This truly is "Music for An Array of Very Good Loudspeakers." This may in fact be true for almost all electronic music.

### The Meaning of Reverberance

Reverberance appears to have great emotional relevance for us. In spite of the fact that it appears to be contrary to survival (because it masks objects in the environments), our response to it is anything but aversive. And this is a place where the sort of loudspeaker array that I have created is powerfully effective beyond any normal acoustical counterpart, including reverberant cathedrals and the like.

The sensation of surround reverberant wash (especially when a height channel is included) appears to be extremely pleasurable, especially for musicians. The ability to generate such reverberance, at will, and in parallel with non-reverberant sounds as desired, gives composers an extraordinarily powerful tool for the generation of loudspeaker music.

Interestingly, here is a case where the evocation of a specific sonic environment (a specific church or concert hall, for instance) is essentially irrelevant. The reverberances I use have no physical counterpart – the key issues pertaining to their use appear to be decay time (from 1 second to 10 minutes), spectrum (where emphasis is placed in the decaying frequency bands) and specific pitches that may be present (as a function of the usually inaudible source that was used to generate the reverberance).

### Limits of Comfort and Safety

Because of excellent loudspeakers' ability to exceed the window of comfortable listening levels on a sustained level, it is incumbent upon the composer/producer to ensure that the

exposure levels do not abuse the listeners. As a general guide, based on a lot of measurements, I suggest an Lmax of 112 dBC SPL in the listening area and an Leq for any given work not to exceed 100 dBC SPL.

Because composers do not usually have much training in either acoustics or noise measurements, they have a tendency to be careless about this. The result can be quite unpleasant, not to mention painful and possibly injurious. In my case and in response to these concerns, I very carefully document levels during production and match them quite precisely (+/- 1 dB) in performance playback. Even so, some people find levels uncomfortable.

### Possible Venues

To maintain specified Sound Pressure Levels while using speakers with the quality of BeoLab 5s, it is important to limit the volume of playback venues. I suggest a volume maximum of approximate 60,000 cubic feet. Further, it is highly desirable for such venues to have limited natural reverberance (< 1.2 secs.?). For the record, my studio has a volume of 8000 cubic feet and a broadband decay time of .5 seconds.

Such music, therefore, cannot go into concert halls or other normal performance venues. It is suitable for home listening (once the overhead speaker is dealt with) and small galleries and museum spaces, to the extent that they are otherwise suitable.

As a result, such music is not going to have a wide audience or exposure. My experience has been, however, that the music is of sufficient power that listeners often seek repeat hearings. It is my hope that I can manage to expand the audience and hearing opportunities for this particular genre over the next decade. I believe the music has real power and validity, and may be of considerable historical performance.

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[1] The loudspeaker as musical instrument: an examination of the issues surrounding loudspeaker performance of music in typical rooms, by David Moulton, presented in Nashville, April, 2003. Available gratis as a PDF from the author at moultonlabs.com

[2] A new loudspeaker design: a case study of an effort to more fully integrate the loudspeaker into the playback room in a musical way, by David Moulton, presented in Nashville, April, 2003. Available gratis as a PDF from the author at moultonlabs.com.

[3] For a fairly comprehensive history of this effort, see the Boston Audio Society Newsletter (The BAS Speaker), Volume 26, #3, available from the Boston Audio Society (www.**bostonaudiosociety**.org)