BOTH SIDES OF THE MIRROR: Integrating Physics and Acoustics with Personal Experience

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My essential desire as a composer is to integrate my knowledge of physics and acoustics with my subjective observations and personal experience -- a process I think of as integrating 'both sides of the mirror'. Several areas of interest have converged to influence my creative work during the past 10 years—from quantum physics, psychoacoustics, linguistics, information technology and systems theory to theatre, film and video. From the seminal influence of John Cage I inherited the understanding that music is organized sound and that the entire field of sound contains infinite possibilities for music.

In the early 1980s a huge explosion of research and technological innovation related to computers produced a revolutionary form of interdisciplinary thinking. Articles in *Computer Music Journal*, for example, covered a vast range of subjects, including physics, linguistics, acoustics, cognitive science and biology. The unifying theme of these disciplines at that time was general systems theory, which describes systems—such as atoms, cells, bodies, families and societies—as irreducible wholes. It describes the behavior of these systems in relation to their environment—the interactive way that biological systems adapt, repair and sustain themselves. In Vancouver, where I was living and studying music at the time, there was a lot of groundbreaking work with sound synthesis and computer music taking place at Simon Fraser University, where I had the opportunity to take a class with Walter Branchi, a composer visiting from Rome. Branchi introduced us to his approach to computer music which he called "composing within sound", in which the frequency ratios of a tuning system formed the basis for all the parameters of the music.

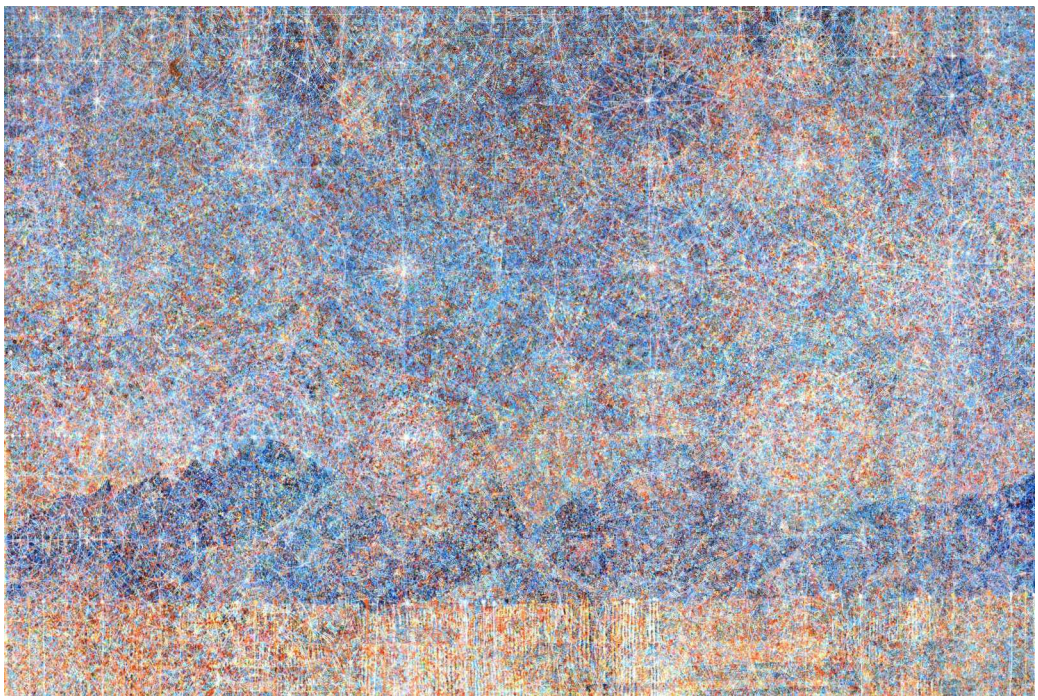

Fig.1. Catharine McTavish, *Night Vision #14: Stars in the Eyes – A Landscape,* acrylic and mixed media on canvas, 396 X 244 cm, 1983-84. (Collection: Art Gallery of Ontario) The painting consists of microscopic points of acrylic paint, all meticulously structured to create a dazzling, web-like patterning.

I was very excited about the potential of computers to work within such detailed parameters of sound, but I became intensely aware of what were, to me, serious limitations. The quality of sound produced by computers was not nearly as interesting or rich as acoustic sound. There was also a physical limitation—I had been diagnosed earlier that year with extreme environmental hypersensitivity, and I became intensely aware of the adverse effects of all electronics and computer technologies on my health due to this condition. I adopted a physical, acoustic approach to music in which my understanding of the physics of sound created a continuum between sound and music. [1] I also worked with intuitive mathematical patterning. This approach is based on a sense of perpetual motion or pulsation similar to, and influenced by, many of the tendencies in minimalist music, but the repeated pitch patterns change much more quickly and occur in more than one part simultaneously, creating several layers of counterpoint. In 1990, when I began to focus on the rhythm and pulsation of the patterning, I began to perceive rhythms as energy systems.

While studying linguistics, I became intrigued by the underlying structural principles that were emerging from many diverse languages. Language can be described as an arrangement of the stream of sensory experiences that result in a certain world order. In the Hopi language, for example, there are no tenses for past, present or future—the division does not exist—and there is no formal distinction between the completion and incompletion of action. This way of thinking resonates with many of the fundamental tenets of contemporary physics, such as the idea that the contrast between a particle and its field of vibration is more fundamental in the natural world than the contrasts of space and time or past, present and future—distinctions that our own language places on our understanding. [2]

Desiring to integrate principles of physics with acoustic sound sources, I discovered that the voice is the acoustic instrument with the greatest potential for timbral transformation.

In the rich and varied tradition of sacred chant, vocal music is structured as a stream of vowels and consonants. This is also true of the ancient tradition of Bulgarian singing, which is based on the drone principle—words are sung on a single, repeated pitch with continuous changes in timbre created by the changing patterns of vowels.

WINTER TREES

In early 1984 I wrote a piece called *Winter Trees* for three female voices, alto saxophone, bassoon and cello. The piece is based on a poem by Sylvia Plath, and the vowels from the poem are used to orchestrate the music, providing an array of resonating spectral elements for each pitch. The voices sing without vibrato. and the voices and instruments often alternate within a narrow frequency range of each other, creating a constant yet continuously changing series of interference patterns. The poem is integrated with the music in such a way that the ear moves freely from sound to meaning, focusing at times on a single line, following a thread of meaning as it slips from voice to voice and, at other times, allowing the assonances and dissonances to wash through it as the voices become submerged in the overall texture. The text provides a lexicon of language sounds, as well as a thread of meaning. The overall shape of the piece is an evolution from a single spectral strand into a continuously changing stream of vowels, percussive vocal sounds and spoken and sung text.

During the time I was working on *Winter Trees* I was becoming more and more interested in physics and acoustics and the implications of recent scientific discoveries for sound and music. I wandered into a small art gallery in Vancouver one afternoon and spent hours with an installation piece that forever changed my way of perceiving things and resolved some of my fundamental questions about the relationship of science and art.

NIGHT VISION #14: STARS IN THE EYES—A LANDSCAPE

Catharine McTavish's work *Night Vision #14: Stars in the Eyes—A Landscape* (Fig.1, Color Plate A, No.1) is one side of an installation piece called Both Sides [3]. The work is an 8 x 12-ft. canvas that hangs from a rod in the centre of a white room and consists of microscopic points of acrylic paint that are meticulously structured to create a dazzling, web-like patterning. The work is a landscape—an image of Vancouver Harbour with the ocean, mountains and sky representing the elements earth, air and water. The visual distinctions between elements are the result of varying degrees of density of the patterning. The web-like patterning is based on a synthesis of optical patterns and subjective observation. McTavish integrated her subjective observation of the visual field around the dimmest star in a night sky with interference patterns found in optical patterns in holography, the Fibonacci number series, cell patterns, light physics and colour perception. The painting contains the entire colour spectrum arranged in a detailed pattern that creates an impression of movement. From a distance the surface of the painting shimmers with silver, pale pink and blue. The entire colour range is perceived only from a close perspective. The painting takes the path of working with detailed patterning based on physics much further that I had imagined possible. It's complex yet visually intoxicating use of interference patterns and colour perception conveys a very deep understanding of the materials of colour and light.

OF RADIANT STREAMS

Of Radiant Streams (1985), for four percussionists and tape, is the first of my pieces that was directly influenced by McTavish's work. I was interested in exploring the physical, acoustic possibilities of percussion instruments, especially through rhythm—rhythm as patterns in space and time, as cyclic repetition, as a pattern with a steady beat. I also wanted to work with a perceptual phenomenon I had read about called "streaming".

> A repetitive cycle of tones spread out over a certain frequency range may be temporally coherent, or integrated, at a particular tempo. It is possible to gradually increase the tempo until certain tones group together into separate streams on the basis of frequency. . . The faster the tempo, the greater the degree of breakdown or decomposition into narrower streams until ultimately every given frequency might be beating along in its own stream [4].

The title *Of Radiant Streams* is a reference to streaming—a perceptual attribute of the auditory system in which the fission of individual elements at high speed creates several streams. The word *stream* is also related etymologically to rhythm; both are rooted in the Greek *rhein*, meaning "to flow".

Another essential element of my piece is room acoustics—I mapped out a general range of resonant frequencies for performance spaces and planned to have the whole room vibrating sympathetically with intense sound pressure by the end of the piece. I began by establishing a frequency range from the extreme registers of the highest and lowest instruments. The highest instrument was the glockenspiel (4, 186 Hz.) played with brass mallets to maximize the high frequency of the sound. The lowest was the bass drum (50 Hz.). I then expanded the frequency range by taping and then playing back the original sounds at up to four times the original speed. The taped part in *Of Radiant Streams* consists of a steady stream of multitracked, acoustic sound with continuous internal timbral modulations. The form of the piece is based on a Fibonacci spiral (Fig.2)—the total duration is 21 min. and the structural points of each recurring cycle occur at 1,2,3,5,8 and 13 mins.

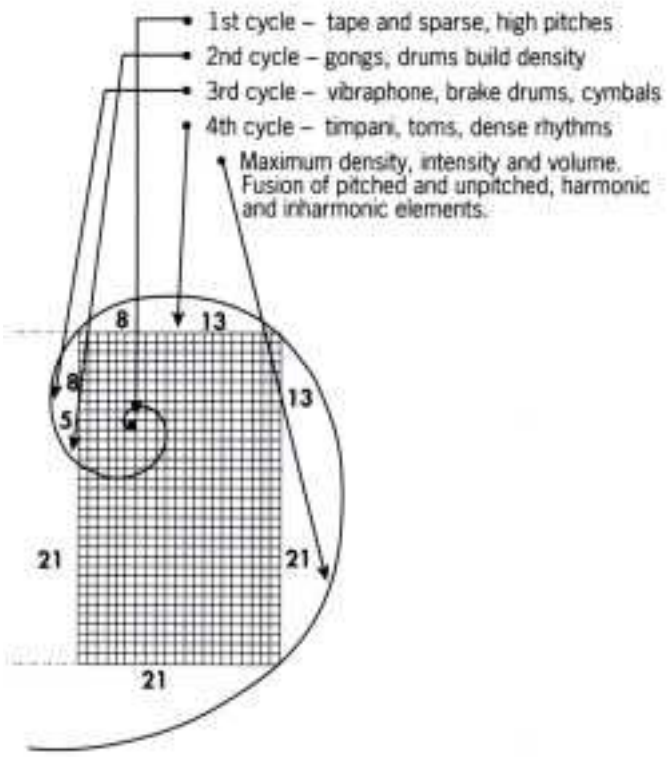

Fig.2. The composer has marked the Fibonacci spiral, which forms the basis of *Of Radiant Streams* (1985), with indications for the recurring cycles within the composition [9]

The piece begins with solo tape— a delicate, sparse texture created with several tracks of antique cymbals (I removed the attack part of the sound, leaving only the resonance). I created the evolution of density and intensity in the pitched sections with fast, repeated note groups that slowly break off into separate streams. Each cycle of the piece consists of an entirely pitched or unpitched section, and the cycles alternate between pitched and unpitched sections. At the 8-min point, the second cycle of the pitched section begins. Fast, repeated note groups (Fig.3) begin at seven or eight notes per second, with the note groups in each part playing pitches within a close frequency range, and all within the frequency span of an octave. As the instruments play note groups of varying speed within the same frequency range, a series of interference patterns is produced, which creates the perception of a large, two-dimensional (2D) field. The note groups slowly expand into a wider range and reach maximum density, intensity and volume (Fig.4) at the 12-min point. The combination of note groups and timbres then create interference patterns with maximum intensity and the fast repeated note groups blur into frequency ranges; the frequency ranges begin to separate into streams. Once the frequency ranges breaks down into separate streams, there is a complete loss of a sense of structures time; each of the percussionists plays note groups as quickly as possible while created a large 2D sound field where individual elements cannot be isolated. The music moves out of a linear sense of time progression and into a large sound field, or texture.

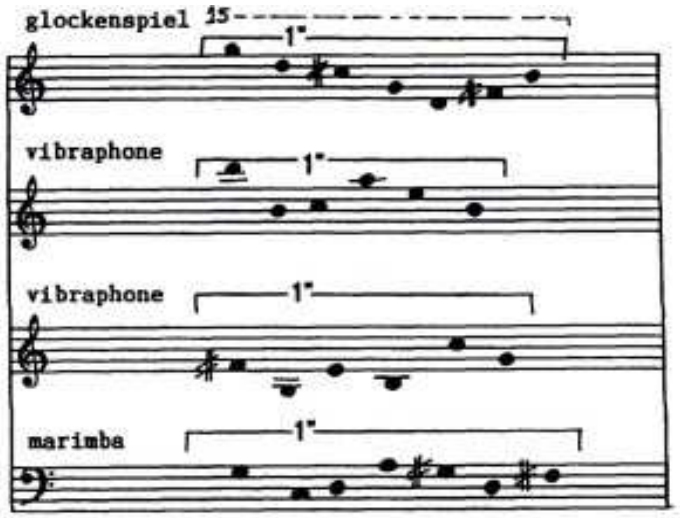

Fig.3. In this excerpt of Of Radiant Streams (1985), the fast, repeated note groups played by four mallet instruments result in interference patterns and auditory pitch segregation, or "streaming."

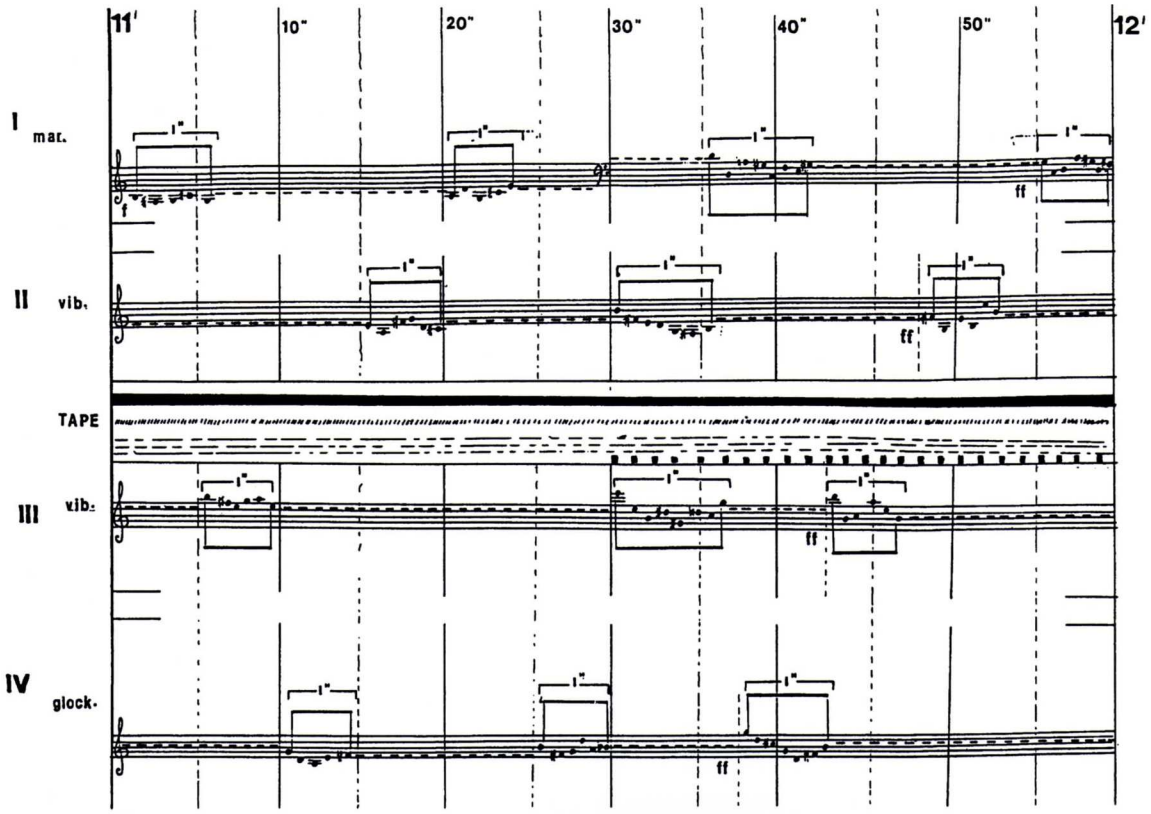

Fig.4. The pitched section of *Of Radiant Streams* reaches maximum density, intensity and volume in this 11-12-min section of the score.

CIRCUITS

Circuits is a piece for female voice and tape that I wrote for Joan La Barbara in 1990-91. During a 10-day period we spent in New Mexico, I studied La Barbara's vocal techniques and worked intensively with the acoustic possibilities of her voice. I was particularly intrigued with her technique of circular singing—pitched singing on the in-breath and out-breath. This technique forms the basis of La Barbara's composition *Circular Song*, a series of ascending and descending pitch glissando on in-breaths and out-breaths. I was also influenced by another form of circular singing known as Inuit throat singing, in which singers mimic sounds of the environment, such as rivers flowing. An intriguing element of Joan La Barbara's performances is the kind of energy she infuses into the music she performs. I began to think of breathing as a rhythmic energy system essential to the physical act of singing, and I wanted to integrate this energy with the physical, athletic quality La Barbara brings to performance.

Circuits is for solo voice and 24-track tape. The harmonic structure of the piece is based on the overtone structures of the most resonant pitches of La Barbara's voice.

La Barbara recorded each individual track in a 24-track recording studio. Multitracking the same voice several times has the effect of reinforcing the particular resonance of that voice, and it creates a kind of simultaneity that takes the music out of a linear sense of time. The multitracked voices create a dense counterpoint that results in an equally dense, textural sound field.

The pitch groups are all based on intuitive mathematical patterning within a general mapping of the overtone series of Eb. With the stark contrast of clear, resonant pitches and breathy unpitched vocal sounds I wanted to integrate the physical demands of singing into the music itself. The entire rhythmic structure is based on a 5-sec cycle of breathing in and out—La Barbara's natural breathing rhythm. In each section, the 24 tracks begin in structured time and gradually move out of it. (Fig5). The combination of these tracks creates a feeling of dissipation. This loss of coherence is the result of each individual track moving slowly out of the established tempo and rhythm of the piece and into a freer interpretation of the material.

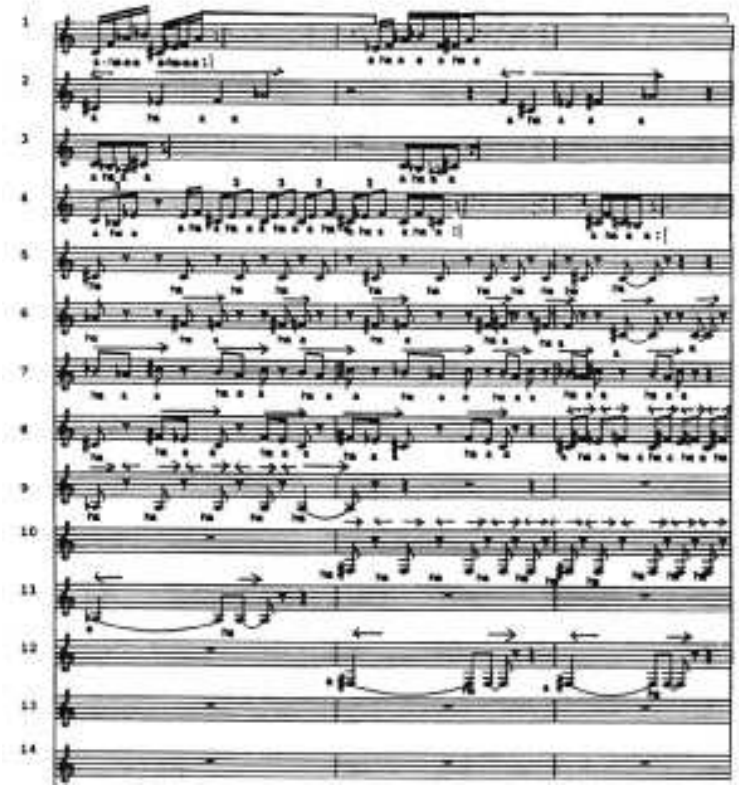

Fig.5. The excerpt from the *Circuits* score for 24-track tape shows where tracks 1,4 and 5 begin to move out of structured time.

RITES OF DECIMATION

One of my most recent works is *Rites of Decimation* (1992), a piece for jazz / new music big band, commissioned by a Toronto-based group called Hemispheres. When I began work on this piece I had been thinking about the dramatic changes taking place all over the world—including the recent drastic events in Eastern Europe. Such symptoms are appearing everywhere and in all areas of life. Our infrastructures are falling apart, causing a breaking down and remapping of everything we think of as boundaries. I wanted to create a compositional structure that would be appropriate to our dissipative situation. I now understand dissipation in the sense that Ilya Prigogine discovered it in physics: initial conditions in the state of a system are associated with being, while laws involving temporal changes are associated with becoming. This is a way of understanding how a process relates to an end result. [5].

I also wanted to integrate some of my knowledge of chaos theory both with elements of randomness and with the repetitive patterns intrinsic to fractals. To do this I organized a continuum with highly structures, notated patterns on one end of the scale and free improvisation on the other.

My intention was also to continue to explore my sense of music as energy systems. I began *Rites of Decimation* with an intuitive sense that I was creating energy systems with rhythm. I had an image of kinetic energy setting up the original impetus, and then sending it through transformations with repetition. Each notated section is repeated several times—but only once as written. With each repetition, the musicians develop the density, intensity and volume of the section. The kinetic energy that sets up the rhythmic structure of each section is created by the percussionists. The underlying harmonic structure and pitch range for each section is indicated by a ”tonality map” (Fig6). The tonality map sets up a sequence of harmonic changes that occur as the must is performed, limiting the performers to a given parameter of all the pitch possibilities for any given point in the piece. The tonality map can be interpreted as a series of individual pitches or spelled out as chords for jazz musicians. All of the instruments follow the same tonality map within the range of their instruments, and each cyclic repetition of the notated sections develops through an expansion of the harmonic spectrum and range of the tonality map. The idea of the tonality map came from a recent computer program called Fractal Music Composer, written by Hugh McDowell [6].

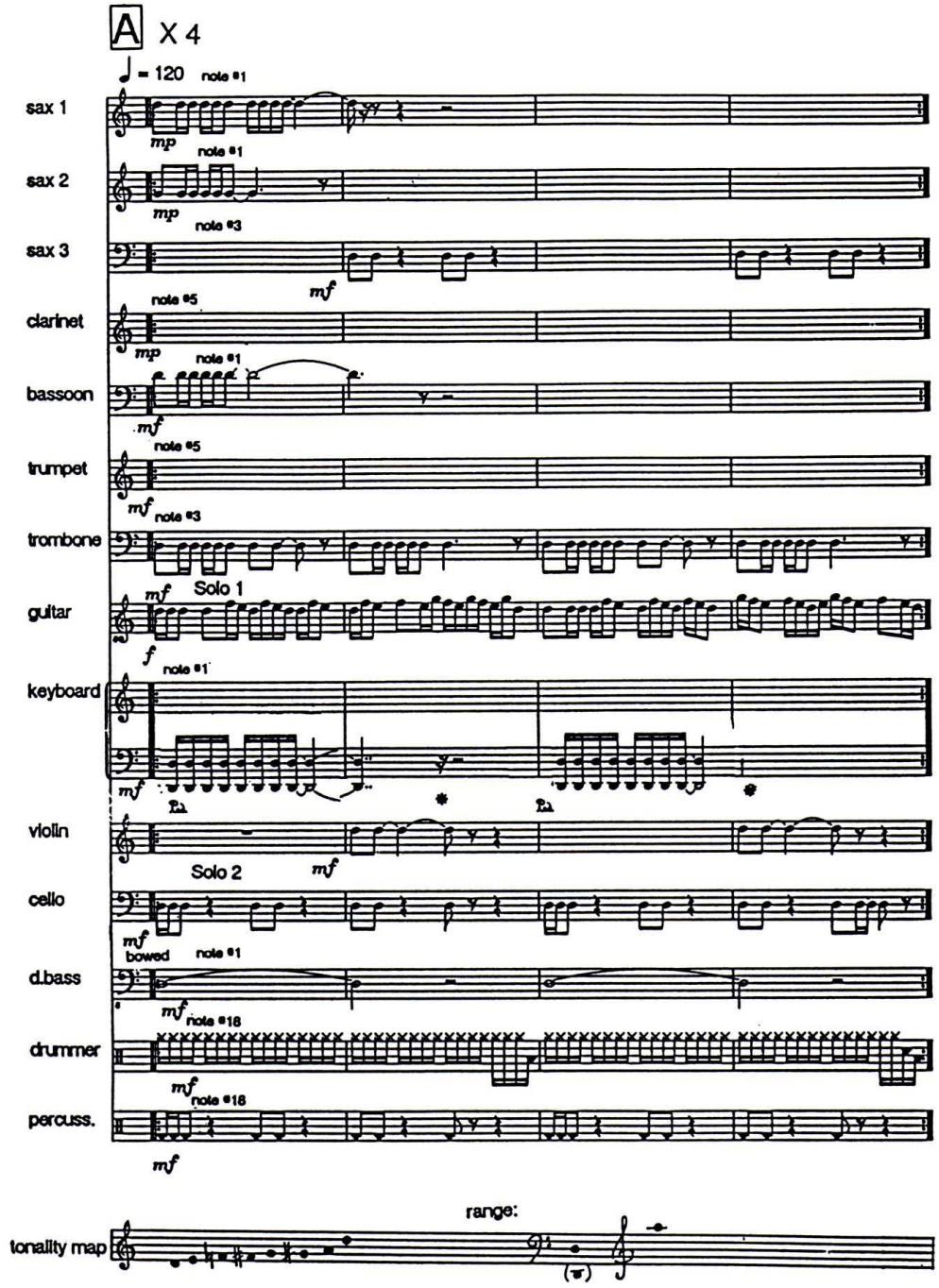

Fig.6. The first page of the score for *Rites of Decimation* is shown here with a corresponding "tonality map"at the bottom.

THE THEATRE AND ITS DOUBLE

One of my most important sources of inspiration is Antonin Artaud, a poet, playwright and visionary who wrote a brilliant and influential collection of manifestos called *The Theatre and its Double.* In his extensive writings he conceived a form of drama that would transform the audience through total emotional and physical involvement. He felt that once theatre was freed from the control of text, it would become an extension of oral / verbal expression beyond words.

Three years ago I began to teach an experimental course at the National Theatre School of Canada, in which the students create theatre from music. We begin this work by using music in the traditional role of text, and then we add layers of other elements—lighting, visual environment, movement and props—during an intensive workshop and rehearsal period before the performance. Each element of the piece is treated as a "character": an integral element of the performance. The music functions as a foundation for the other elements.

The approach used in this experimental course has led me to create various forms of interdisciplinary work, including *Body Weather*, the working title of a multidisciplinary piece (currently in the early stages of development) and, most recently, a film project.

POWERLINES

Powerlines (in progress) is the title of my film project—a 16mm, 50-min experimental documentary film. The theme of the film is the deterioration of the environment caused by electromagnetic pollution and is based on my perceptions and experience of electromagnetism. Electromagnetic pollution can be understood to be caused by out-of-phase electrical oscillations, or incoherent energy systems. As many North American cities are in the process of falling into their crumbling Victorian networks of sewers, the environment is being flooded with electromagnetic radiation of most wavelengths and with varying degrees of coherence, with more and more demands being made for frequency allocations in the already densely overcrowded electromagnetic spectrum. (Fig.7) I am researching the implications of this process in close consultation with Dr. Andrew Michrowski, a Canadian scientist who specializes in issues of electromagnetic pollution [8].

Powerlines integrates documentary images of power lines, power generators and transformer stations with images that I have created and transformed with Amiga-based computer imaging systems.

The film is built around a dancer who describes in movement her personal response to the environment and who interacts with the electromagnetic fields. Her minimal, expressionistic movements are influenced by Butoh, a dance form that emerged in post-World War II Japan and that expresses in movement the devastating effects of the atomic bomb. Her interaction with electromagnetic fields will be filmed in a room with video display terminals. There will be close attention to lighting, and the room will be misted with water vapour to make the radiation from the video display terminals visible. The sounds of the electromagnetic fields and the interaction of the fields with the human body will be made audible with the use of a device, created by Michrowski, that registers and amplifies sounds in the electromagnetic spectrum. This will reveal sounds such as those from radar installations and the microwave landing patterns of planes.

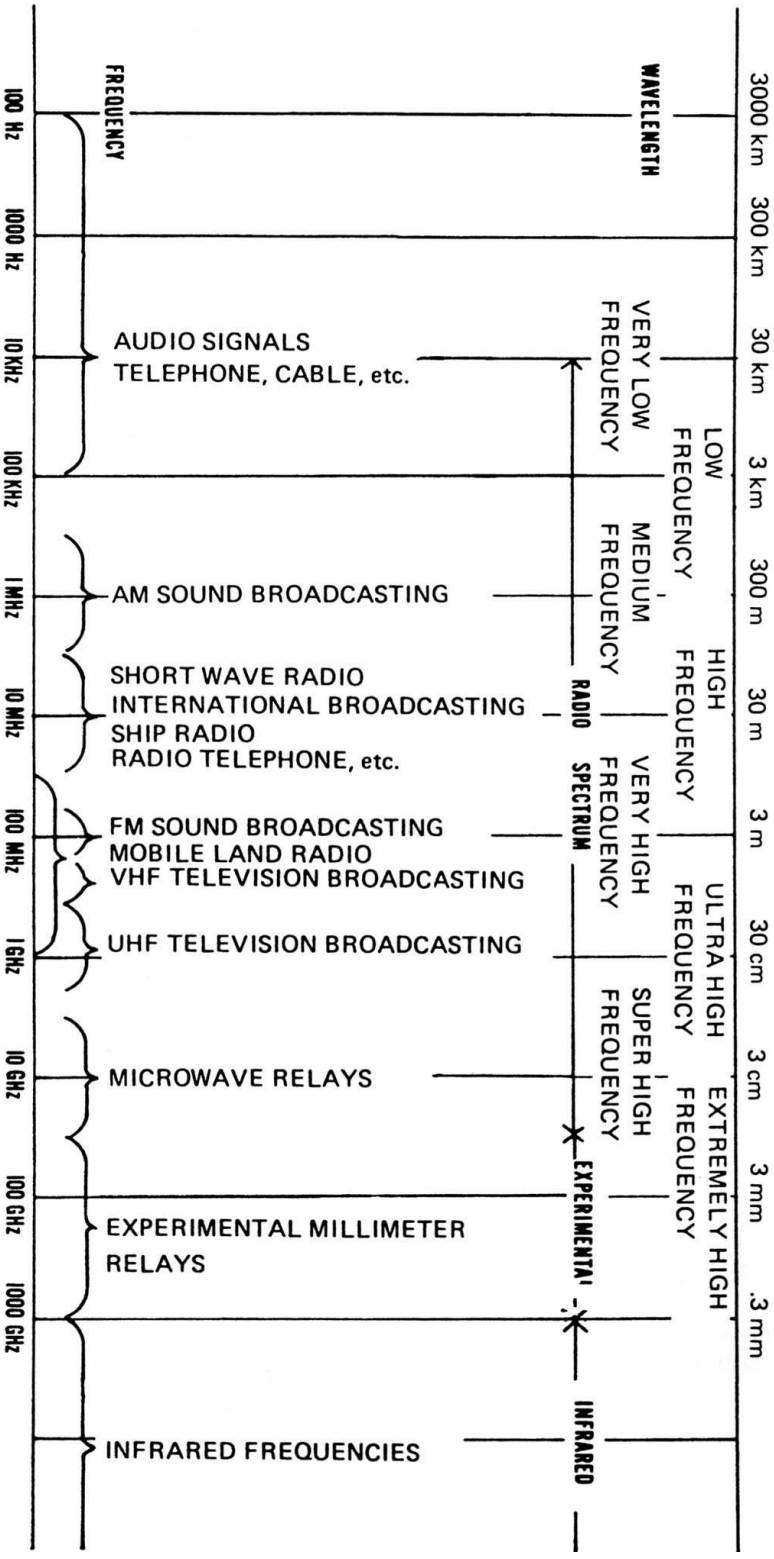

Fig. 7. This cross-section of the electromagnetic spectrum [10] shows the frequency bands and wavelengths allocated for communication. *Powerlines* includes sounds from the spectrum of audio signals to the spectrum of microwave relays.

I will use computer imaging of the power lines to create a gradual disintegration of the structures themselves, leaving traces of the electromagnetic energy patterns along the power lines. The disintegration of the original images will occur with the same visual phrases as the original images. I will vary and transform the patterns of the steel structures of microwave towers with computer imaging. The variations of images of power generators that I create will be edited with the fast, mechanical rhythm of the generators, creating a rhythmic disintegration of the images.

The music integrates found, environmental sound—the 60-Hz hum of power lines and transformer stations, the mechanical, rhythmic sounds of power generators, the high-frequency sounds of computers, fax machines and cellular phones, and the extremely low frequencies (ELF) from video display terminals. More sounds will be recorded with Michrowski's device—the sounds of traffic lights, car phones, radio towers and satellite dishes. I will develop more sounds with the interference patterns created with car radios in close proximity to high-tension power lines. The movement of the theme toward transformation and re-integration will be expressed through a transformation of the music to a more harmonic rhythmic language. Finally, the stage of re-integration will be expressed musically with the integration of the sampled sounds of acoustic instruments (violin, cello) and percussion instruments with computer-generated and synthesized sounds, which will be grounded in coherent rhythmic structures, and with music based on the overtone series and on principles from chaos theory.

I will create the transition to more coherent energy systems visually with images based on principles that represent coherent energy systems. For example, I plan to use images of the U.S. pavilion (now known as the "biosphere") from the Expo '67 site in Montreal, Canada. This structure was designed by Buckminster Fuller and is based on harmonic geometric principles. Other images include the symbol of the Sri Yantra—a Hindu symbol that represents an ordering of chaos—seen as a simultaneous, rather than a linear time process. In the context of the film, the symbol represents the integration of the individual with the environment. These images will be subjected to as many computer-imaging and optical-printing techniques as possible, in order to create endless variations and to put the images themselves through a process of transformation and re-integration.

I am developing the basic building materials of the film—the music, visual images and dance—contrapuntally and grounding them in rhythm. I am arranging the relationship of the different elements in the form of a "score", in which each element is notated and organized in layers. The music, visual images, and dance will evoke disintegration and deterioration by functioning somewhat independently; throughout the film, these three elements will go through a process of transformation. As part of this process they will become re-integrated and synchronized. I think of each element as an independent instrument, or part, that interacts with the other parts contrapuntally and rhythmically through time.

CONCLUSIONS

With *Powerlines* I began to transpose compositional techniques of multitracking, counterpoint and rhythm to film. I am interested in working in greater detail with rhythm as an energy system through the soundtrack for this film. I hope to find a way to work with rhythm that defies gravity, creating a rhythmic structure whose centre cannot be fixed—just as the rhythm of breathing in and out formed with structural basis of Circuits, and an image of kinetic energy formed the starting point of *Rites of Decimation*, setting up an original impetus and sending it through transformations. Tonality has a sense of a loss of gravity when a harmonic structure is missing the fundamental pitch, and I would like to create a sense of a loss of gravity with rhythmic structures that emphasize the beat while transcending it.

BODY WEATHER

My next project is *Body Weather*, a multidisciplinary piece for which I will create music entirely from computer-generated and sampled sound sources. The music will be combined with digitally-processed images and a sound system that completely surrounds the audience to create a form of multisensory experience. This experience will create a sense of disintegration by surrounding the audience with fast, dense, rhythmic music and images resulting in a matrix where the boundaries of the self do not apply.

The theme of *Body Weather* is disintegration—the positive aspects of the loss of the boundaries between the individual and the environment, of the breakdown of the immune system and the loss of an ego-based sense of individuality. The theme is based on my experience of the disintegration of the boundaries between myself and the environment, caused by my environmental hypersensitivity. This experience resonates with one of the basic tenets of systems theory, which describes the boundaries between the individual and the environment as being very fluid.

The positive aspects of such an experience are that we become aware that we are an integral part of a system much larger than ourselves and that the more integrated we are with this larger system, the more differentiated we become. This disintegration of boundaries then extends to boundaries between races, genders and sexual orientations and so on.

The theme will be expressed in the music and images used and, through a close relationship between the performers and audience, created in part with interactive computer systems. The images and music will be synchronized in dense, fast patterns based on dance rhythms.

Acknowledgements

For valuable support, feedback, and technical advice during the process of writing this article I am indebted to Catharine McTavish, Shahrokh Yadegari and Gayle Young. For technical advice, inspiration and support for *Powerlines* I am indebted to Andrew Michrowski.

References and Notes

1. Some of the pieces (*Winter Trees, Of Radiant Streams, Circuits*, and *Rites of Decimation*) I describe here are included on my compact disk *Both Sides* (1994), produced in Montreal by Société Nouvelle d'Enregistrement, 10175 Meunier, Montreal, Quebec H3L 2Z2 Canada

2. Benjamin Lee Whorf, *Language, Thought and Reality* (Cambridge, MA: MIT Press, 1956) pp.51-56

3. The other side of the canvas, called The Pure Gold Baby that Melts into a Shriek (a quote from Sylvia Plath's poem "Lady Lazarus") is a disturbing, visceral image made with deep lacerations that scar the canvas, acupuncture needles that pierce through the surface of the canvas and large splashes of McTavish's own blood. It is evidence of what McTavish endured to create the "other " side—the "art" side of the installation.

4. Albert Bregman and Stephen McAdams, "Hearing Musical Streams", Computer Music Journal 3, No.4, pp.26-43

5. Ilya Prigogine and Isabelle Stengers, *Order Out of Chaos: Man's New Dialogue with Nature* (New York: Bantam Books, 1984)

6. Ian Waugh, "Harmony From Chaos", *Atari ST User Magazine* (August 1992) pp.16-18.

7. Antonin Artaud, The Theatre and Its Double (New York: Grove Press, 1958).

8. For more information, contact The Planetary Association for Clean Energy Inc., A. Michrowski, President. 100 Bronson Avenue Suite 1001, Ottawa, Ontario K1R 6G8 Canada.

9. Fibonacci spiral reprinted from Matila Ghyka , *The Geometry of Art and Life* (New York: Dover, 1977).

10. Reprinted from *Handbook for Acoustic Ecology* (Vancouver: A.R.C., 1978).

Discography

Helen Hall, Both Sides (Société Nouvelle d'Enregistrement, 1994), Compact Disc.

Helen Hall, "Winter Trees" and "Stoicheia", *Bridging Language*
(Musicworks 1986) Cassette

Filmography

Helen Hall, *Powerlines* (Montreal, Cinefort Inc., 1994). Distributed internationally by Cinema Libre.