UNIVERSITY OF MIAMI

HAWKING SONIFIED: THE COMPOSITION OF A PATTERN/PULSE PIECE THAT ILLUMINATES THE LECTURES OF STEPHEN HAWKING

By

Lawrence W. Moore

A DOCTORAL ESSAY

Submitted to the Faculty
of the University of Miami
in partial fulfillment of the requirements for
the degree of Doctor of Musical Arts

Coral Gables, Florida

December 2012

UNIVERSITY OF MIAMI

A doctoral essay submitted in partial fulfillment of
the requirements for the degree of
Doctor of Musical Arts

HAWKING SONIFIED: THE COMPOSITION OF A PATTERN/PULSE PIECE THAT ILLUMINATES THE LECTURES OF STEPHEN HAWKING

Lawrence W. Moore

Approved:

____
Ferdinando De Sena, D.M.A.
Associate Professor of Music Theory
and Composition

____
M. Brian Blake, Ph.D.
Dean of the Graduate School

____
Raul Murciano, Jr., D.M.A.
Program Director, Media Writing and
Production, Music Theory and Composition

____
Lansing McLoskey, Ph.D.
Assistant Professor of Music Theory
and Composition

____
Colby Leider, Ph.D.
Program Director, Music Engineering
Associate Professor of Music

MOORE, LAWRENCE W. (D.M.A., Music Theory and Composition)
Hawking Sonified: The Composition of a Pattern/Pulse Piece that Illuminates the Lectures of Stephen Hawking (December 2012)

Abstract of a doctoral essay at the University of Miami.

Doctoral essay supervised by Professor Ferdinando De Sena.
No. of pages in text. (51)

Hawking Sonified is a piece composed in homage to the great cosmologist and theoretical physicist, Stephen Hawking. The piece is a four movement work that musically illuminates four selected lectures given by Professor Hawking in his own, uniquely synthesized voice. The compositional approaches are indicative of the Pattern/Pulse school of minimalistic composition. *Palsplit* 2 and *Palsplit 4*, the software environments used to compose the piece were created by Lawrence Moore using the Pure Data computer music programming language. The software modules contained achieve the musical effects through looping recorded lecture examples at various intervals and processing the audio through band pass filters and amplitude envelopes that generate pulsing effects. These processes combined with spatial manipulation within an octophonic speaker system create a musical realization of the topics discussed in the selected lectures. The selected lectures cover the physical phenomena of entropy, the event horizon of black holes, expansion of the universe in imaginary time, and the expansion of the universe in real time.

CONTENT

LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

As a computer music composer whose interests include pattern pulse music and timbral manipulation, I have elected to focus my dissertation on composition of a piece which employs rhythmic, timbral, and spatial processes to create patterns of pulsation, and the design of computer music software to facilitate creation of this piece. The pattern pulse pieces that I find most intriguing are process pieces that utilize the manipulation of speech rhythms and timbre, such as Steve Reich's *Come Out*[1] and Alvin Lucier's *I am Sitting in a Room*[2]. My doctoral composition is a multi-movement piece with a duration of approximately 20 minutes that employs a variety of approaches to rhythmic and timbral speech processing.

I also have a strong interest in cosmology and theoretical physics. This interest has inspired me to select recorded lectures of Dr. Stephen Hawking to utilize in this piece. The selected lecture excerpts describe physical phenomena. These descriptions are rhythmically and temporally manipulated in ways that sonically depict the subject matter discussed.

---

[1] Steve Reich, *Early Works*, Nonsuch 1242768, 1992, CD.

[2] Alvin Lucier, "I am Sitting in a Room," *I am Sitting in a Room*, Lovely Music B00000INI7, 1990, CD.

Audio examples accompany this proposal on the companion CD. The audio examples are an integral part of this proposal. By referring to these examples it is possible to draw a clear picture of the style and materials of this piece.

Hawking is an eminent cosmologist and theoretical physicist, who is well known to the general public through books like *A Brief History of Time*[3] and *The Universe in a Nutshell*[4]. He has also released a number of audio recordings of his lectures. These lecture recordings are recorded utilizing his speech synthesizer created by David Mason of Cambridge Adaptive Communications. In the mid 1980s, Dr. Hawking's progressing ALS symptoms reached a point at which his deteriorating vocal cords needed to be surgically removed. Hawking was given Mason's computerized speech synthesizer, which was highly advanced during the mid-1980s. Hawking uses the synthesizer manually, selecting and triggering his words from a graphic display. While technology in speech synthesis has improved over the years, he has maintained the same synthesizer to preserve his unique voice which is recognized the world over.

While listening to a series of recordings entitled *The Cambridge Lectures*[5], I realized that some of the physical phenomena he described could be musically portrayed. I selected some excerpts which I thought would lend themselves to rhythmic and timbral processing and would be analogous to the physical phenomena being described. Each movement of the piece is characterized by a specific excerpt and collection of processes.

---

[3] Stephen Hawking, *A Brief History of Time* (New York: Bantam, 1988).

[4] Stephen Hawking, *The Universe in a Nutshell* (New York: Bantam, 2001).

[5] Stephen Hawking, *The Life Works of Stephen W. Hawking: Cambridge Lectures*, (New York: Audio Literature, 1996), cassette.

CHATPER II

SOFTWARE COMPONENTS AND MUSICAL DEVICES

Rhythmic Processing Using Amplitude Pulsing

The software designed for this composition has general capabilities to enable different collections of processes. *Pure Data*[6] is used to create the software tools that are employed. *PD* is a computer music programming language that allows the user to design a seemingly endless variety of signal processing modules, called patches, and also allows the programmer to create graphic interfaces for interacting with the patch.

In the aforementioned Steve Reich piece, *Come Out*, Reich uses a continuously looped audio recording of the words "come out to show them" as a subject to undergo gradual signal processing. The main method that Reich uses in the piece is phasing. By playing multiple continuous loops of the audio which become progressively offset in time, Reich creates an intriguing array of gradually changing rhythmic effects. These rhythmic effects create accents that appear and disappear as the different portions of the waveforms either reinforce or attenuate each other.

Using *Pure Data*, I have designed a patch which I call *Pulse Amp* that utilizes amplitude envelopes that are continuously repeated by an oscillator. As the amplitude envelope cycles, a rhythmic pattern is created. Figure 1 illustrates the graphic interface for this patch. In Audio Example 1 (Audio CD Track 1), *Puls*e *Amp* is used to modulate a sine tone at 1.6 cycles per second. The amplitude envelope used is a cosine waveform

[6] Pure Data 0.39, Miller Puckette, La Jolla, CA, 1999.

(which is also illustrated in Figure 1). The frequency of the amplitude oscillator can be adjusted, which yields varying speeds of the pulsing effect. In Audio Example 2 (Audio CD Track 2) the speed of the oscillator is increased during the course of the example.

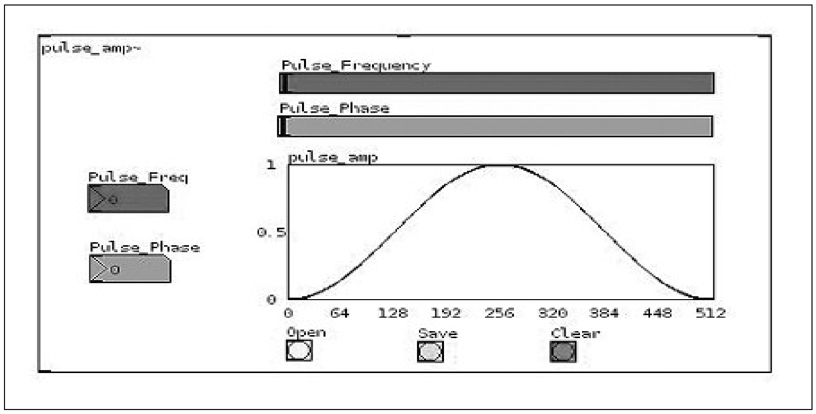


Fig. 1 - The graphic interface for *Pulse Amp*

Another patch, *Pulse Amp Maker* facilitates the creation of different shapes of amplitude envelopes through point plotting. Figure 2 shows the graphic interface of this patch with a triangular shaped envelope. The controls at the right side of the patch are used to set the y-axis values and the controls at the bottom set the x-axis values. Audio Example 3 (Audio CD Track 3) demonstrates the oscillating triangle envelope's effect on a sine tone. The frequency of the amplitude oscillator increases over the course of the example.

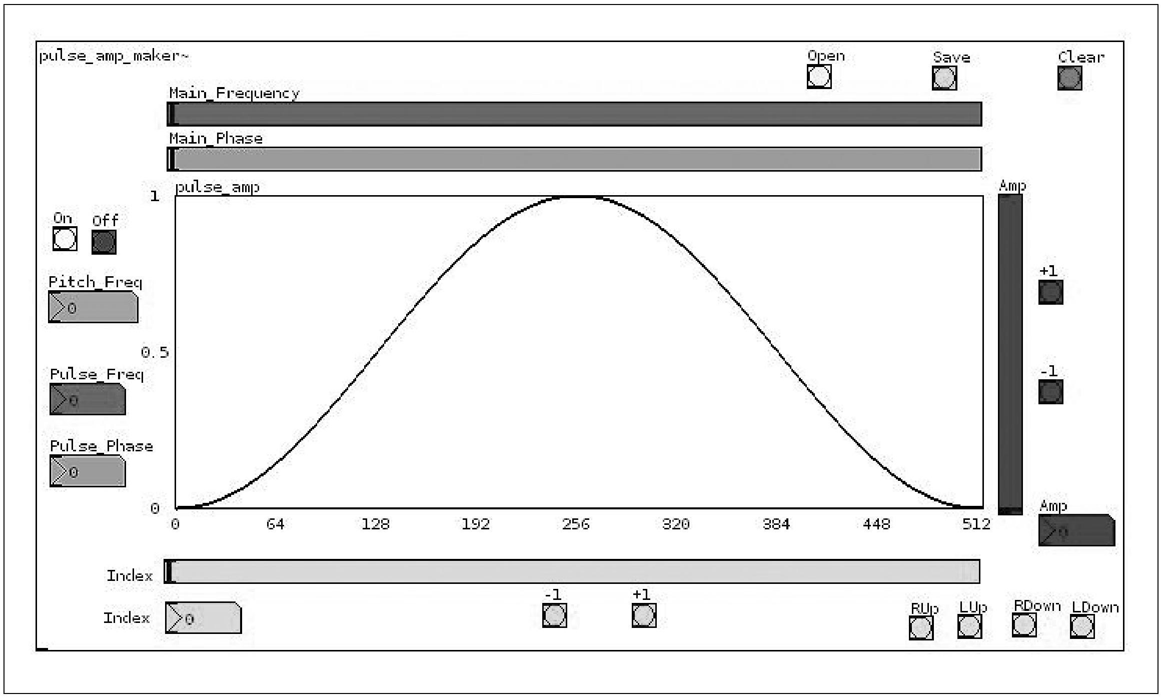


Fig. 2 - The graphic interface for *Pulse Amp Maker*

Using *Pulse Amp Maker*, one can also create amplitude envelopes that generate grouped rhythmic figures. Figure 3 illustrates a triple rhythm. This rhythmic figure is demonstrated in Audio Example 4 (Audio CD Track 4); the pulse frequency is gradually increased over the course of the example.

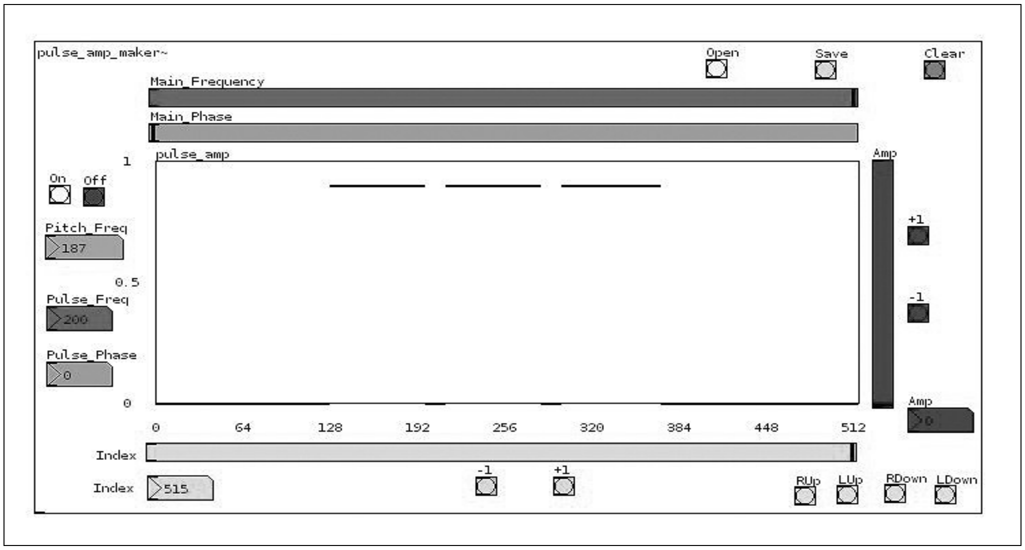


Fig. 3 - A triple figure created using *Pulse Amp Maker*

Another feature of *Pulse Amp* is phase control. This parameter allows one to shift the phase of the amplitude oscillator. When using multiple *Pulse Amp* modules, one can use the phasing as an additional effect. Audio Example 5 (Audio CD Track 5) demonstrates this effect by performing the original cosine envelope (Figure 1) on the left and right channels. While the frequency of the pulsing oscillator is maintained, the phase of the right channel is gradually adjusted between 0 and 360 degrees. The gradual shift in phase displaces the timing of the pulses in the left and right channel. The effect is a subtle one when used with a sine tone, but is more pronounced when recorded speech patterns are used.

Utilizing *Pulse Amp* over Looped Speech Patterns

I have created another *Pure Data* patch called *Looper*, which allows the user to load audio clips that can then be looped from defined start and end points within the audio clip. Figure 4 illustrates the graphic interface for *Looper*. Audio Example 6 (Audio CD Track 6) is one of the selected excerpts from Stephen Hawing's Cambridge lectures. This excerpt is a description of the process of entropy in which Hawking describes the mixing of molecules as a natural example of a progression from order to disorder. In Audio Example 7 (Audio CD Track 7), a loop is created between the 9th and 19th second of the audio clip. The start and end time of the loop point are rounded to seconds in this example; however, they can be set at a resolutions down to the millisecond. The sound of the audio file rewinding from the end point to the start point is used in some instances as an alternate effect.

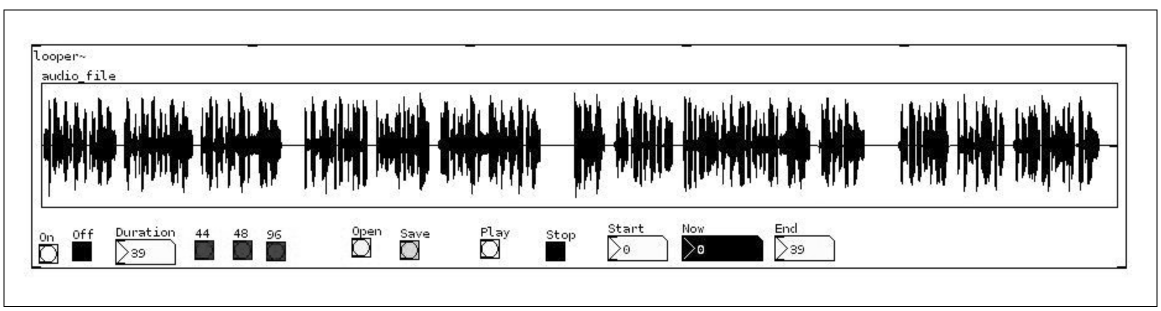


Fig. 4 - The graphic interface of *Looper*

In order to demonstrate how *Looper* can be utilized with *Pulse Amp* to create rhythmic pulsing of the spoken audio files, I have created a patch using one instance of *Looper* and two instances of *Pulse amp*. *Pulse Amp Stereo,* which has been created for convenience in recording stereo examples of *Pulse Amp*'s capabilities, is illustrated in Figure 5.

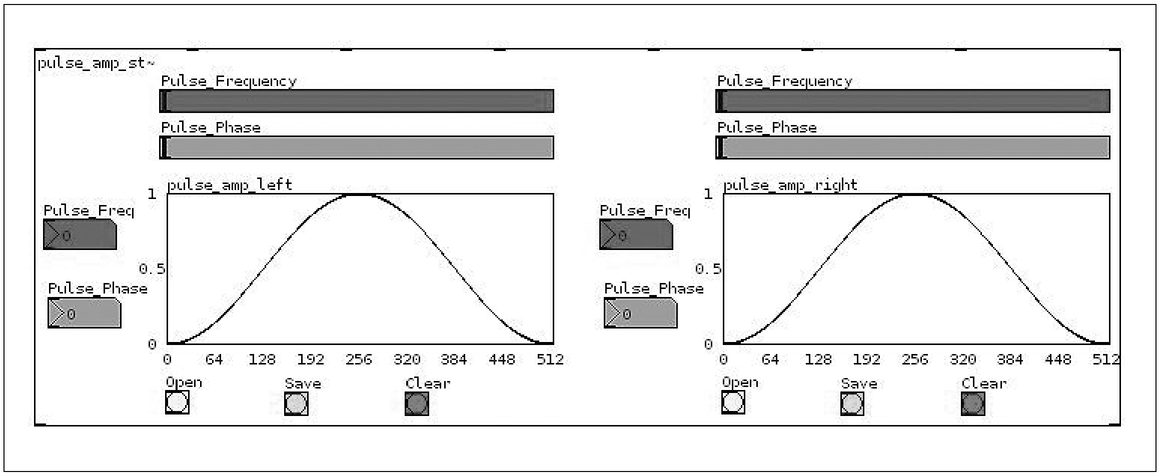


Fig. 5 - The graphic interface of *Pulse Amp Stereo*

In Audio Example 8 (Audio CD Track 8), the same looped audio from Audio Example 7 (Audio CD Track 7) is used. In this example, however, the audio is sent through channels of *Pulse Amp Stereo*. The triple rhythm amplitude envelope from Audio Example 4 (Audio CD Track 4) is used on both channels. Both channels begin cycling at 18 cycles per second. The frequency in the right channel is gradually reduced to 0.99 cycles per second. The frequency in the left channel is then reduced until it reaches 0.88 cycles per second. This demonstrates that *Pulse Amp* and *Pulse Amp Stereo* can be used together to create a modulation effect at high frequencies and a sporadic opening and closing effect at low frequencies. In Audio Example 9 (Audio CD Track 9), the same loop is used with both the left and right channels set at 13.05 cycles per second. The right channel, however, is set 180 degrees out of phase with the left channel. Over the course of this example, one can hear the subtle effect of phasing reminiscent of phase pieces such as Steve Reich's *Come Out*. This effect is gradual over the 2 minute and 29 second example because phase changes, which are inherently minute differences at the cyclical level, become more pronounced over the full duration.

Timbral Effects

In the aforementioned piece, *I am Sitting in a Room*, Alvin Lucier uses a recording of his spoken word narration that literally states the process that the audio recording undergoes over the course of the piece. The audio clip is repeatedly recorded from playback speakers into a microphone in a continuing process. Each time that the recording is re-recorded, the resonant frequencies of the room reinforce themselves.

In order to provide timbral pulsing effects for my piece, I have elected to use multi-band frequency filtering to separate the lecture recordings into multiple channels that are individually composed of separate frequency ranges. These separate parts are then be routed to separate channels that are affected by different instances of *Pulse Amp*. As a result, different frequency ranges have different pulse patterns, thus creating a joint control over rhythm and timbre.

Figure 6 illustrates the patch, *Bandsplit 2*, which takes audio input and splits it into two different bands, which are defined by a specific frequency value. This frequency value separates the lower frequencies by using a low pass filter while the high frequencies are set by a high pass filter. The two separate frequency ranges are then sent out as two separate audio channels.

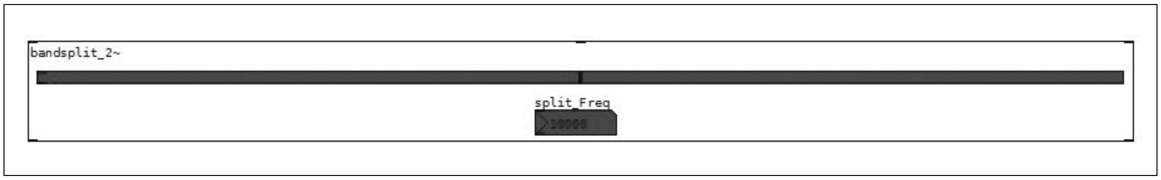


Fig. 6 - The graphic interface of *Bandsplit 2*

Audio Example 10 (Audio CD Track 10) is a recording of a full-length lecture excerpt being routed through *Bandsplit 2*. The first channel value in *Bandsplit 2* is set to 400 Hz. The example begins with only the low frequency channel, which is routed through *Pulse Amp* using the triangle envelope cycling at 1 cycle per second. The high frequency channel enters half way through the example passing through an instance of *Pulse* Amp using the triangle envelope cycling at 7.23 Hz. As a result, the two frequency ranges have distinct rhythmic pulsing effects.

In order to take this method further, I have also created *Bandsplit 4*, which allows for the division of the lecture examples into 4 separate bandwidths, which can then be routed to separate instances of *Pulse* Amp. Figure 7 shows the graphic interface for *Bandsplit 4*. *Bandsplit 4* uses three split points in order to define the 4 separate channels.

Fig. 7 - The graphic interface for *Bandsplit 4*

In order to apply amplitude modulation to the four resulting bands individually, I have created the patch *Pulse Amp Quad*, which combines four instances of *Pulse Amp* into one patch. Audio Example 11 (Audio CD Track 11) demonstrates the use of *Bandsplit 4* and *Pulse Amp Quad* with *Looper.* The frequency bands have been defined by split point 1 being set at 300 Hz, split point 2 at 700 Hz, and split point 3 at 1200 Hz. The first band (frequencies below 300 Hz) is routed through an amplitude modulator utilizing the triangle envelope, set at 12.70 cycles per second. The second band (frequencies between 300 Hz and 700 Hz) is routed through the triple envelope at 15.6 cycles per second. The third band (frequencies between 700 Hz and 1200 Hz) is being modulated by a triangle envelope set to 21 cycles per second. The fourth band (frequencies above 1200 Hz) is passed through a triplet envelope set at 11.7 cycles per second. Each of the bands fades in, one at a time, over the course of the example.

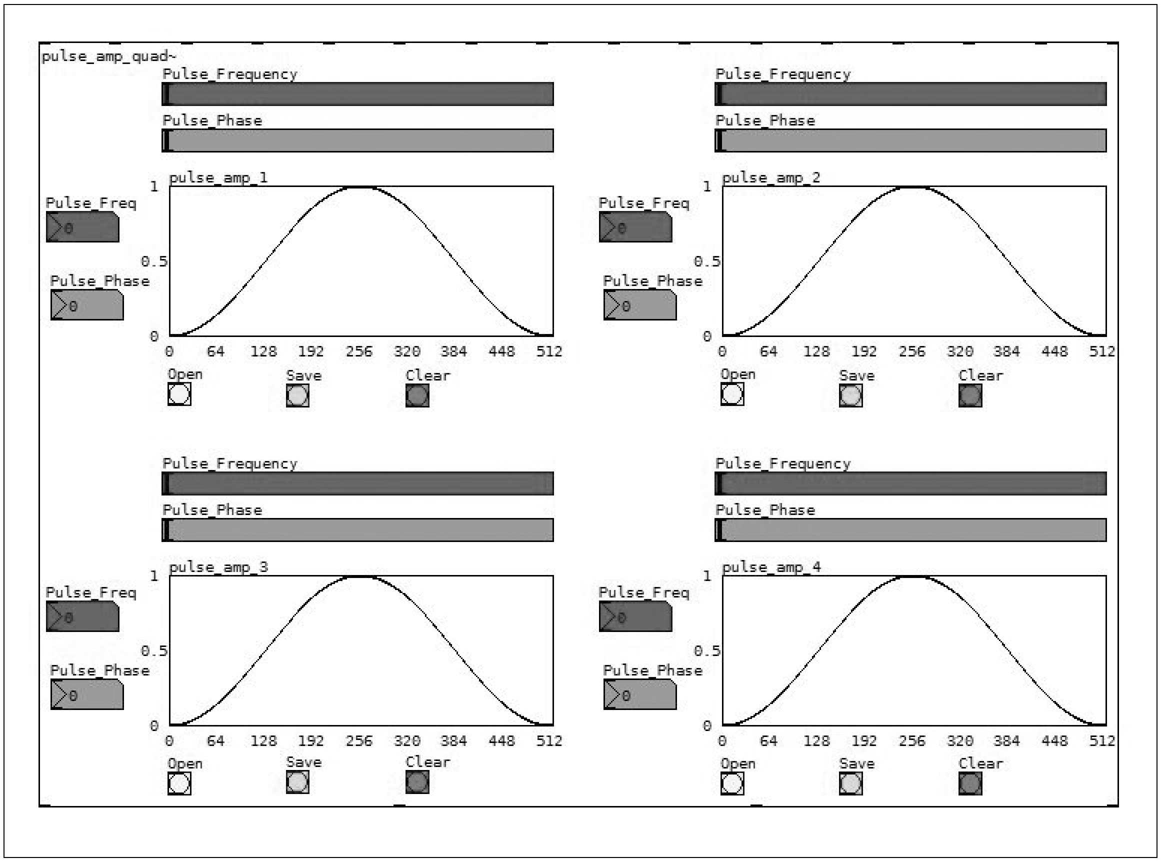


Fig. 8 - The graphic interface for *Pulse Amp Quad*

Spatial Manipulation

In an effort to add spatial manipulation to the rhythmic and timbral elements of the piece, I have created patches that are capable of taking the audio signals that have been routed through the other patches and control their spatial panning within an eight channel field. An 8 channel field consists of two front speakers, two rear speakers, and center speakers placed at the sides, the front, and the rear of the listening area. I use proximity panning as the primary technique to place sound within the 8 channel field. Just as X and Y coordinates are used to plot points within a two-dimensional field, I se X and Y coordinates to plot the location of sound. The strength of the signal is defined by the proximity of the plotted sound point to the eight different speakers. Figure 9 illustrates the 8 channel sound field and how the X and Y panning coordinates can be plotted within this field. Both X and Y plotting coordinates range in value from -50 to 50 as illustrated in the figure.

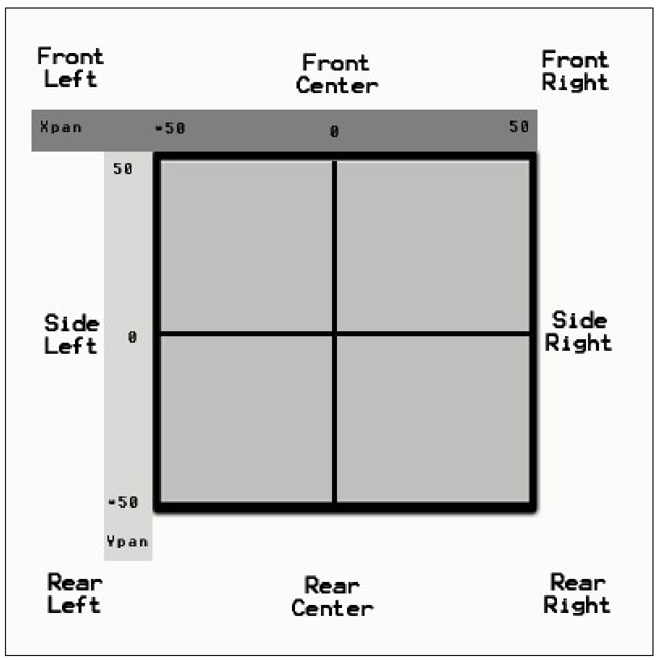


Fig. 9 - Proximity panning in an otophone sound field

I have also created a series of mixers that have two, four, and eight channels that is used depending on the number of discrete audio signals that are sent to them. Each of these mixers is capable of plotting X and Y coordinates for the spatial placement of each audio channel. The mixers also have volume and mute parameters for each channel. Figure 10 illustrates the graphic interface for the four channel mixer, *4x8 Mixer*.

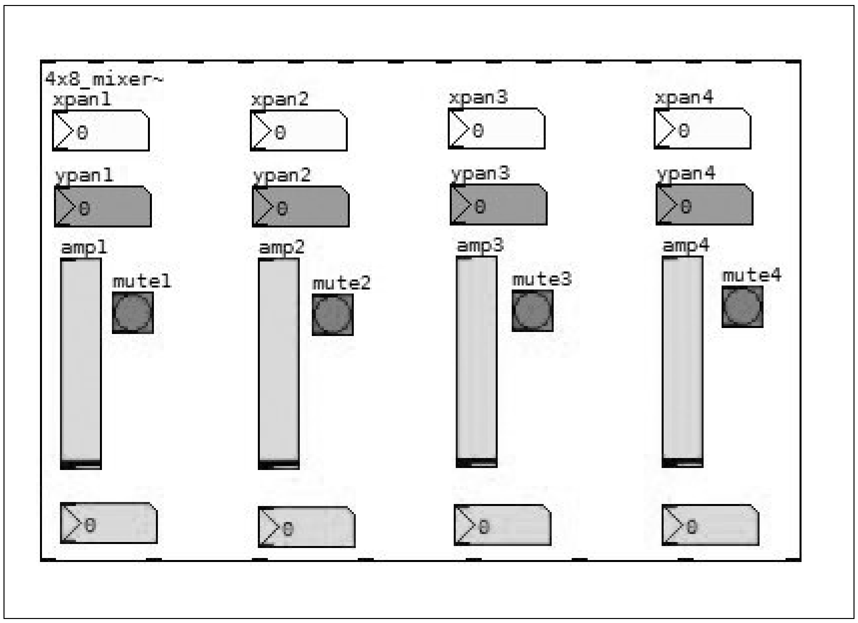


Fig. 10 - The graphic interface of *4x8 Mixer*

Controlling the Music Using Arrays

Looper is the source for audio playback of the lecture excerpts for the piece. *Pulse Amp* allows for rhythmic modulation of the source audio. *Multiband* patches allow for timbral manipulation and division of the source material. Finally, the *mixer* patches allow for spatial positioning of all divisions of the processed source audio. Each of these elements has parameters that control the different musical gestures that these patches process and create. Control of these parameters over time is the stage that brings all of the elements together. In *Pure Data*, arrays are graphic tables that store numeric values that can then be sent to the various modules in a combined patch. The arrays then serve as vector components within a graphic score that routes parameter values to different modules continuously in the same way that MIDI tracks send note and controller values to instruments within a MIDI sequencer.

Figure 11 shows arrays that I have created to control the speed of the amplitude modulation oscillators from *Pulse Amp Stereo*. The vertical axis of the arrays show the range of values from 0 to 2000, representing the cycle period in milliseconds, that set oscillator speeds in the range of 0 – 20 cycles per second. The horizontal axis of both arrays measures elapsed time in seconds. The data in the arrays can be drawn in using the mouse or accurately set point by point, using the button controls that I created as part of the arrays' user interface.

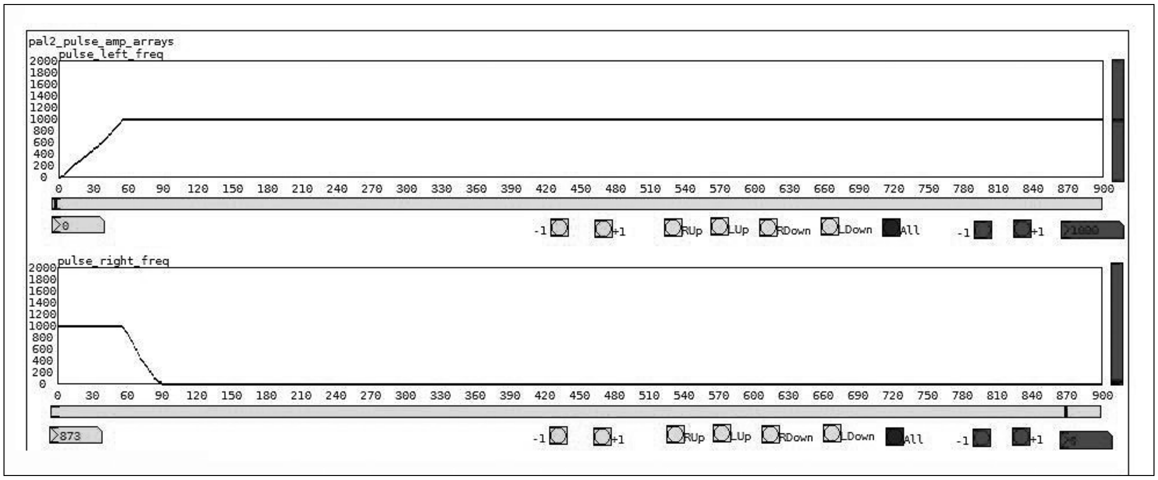


Fig. 11 - Arrays the store values for *Pulse Amp Stereo*'s frequency settings

Audio Example 12 (Audio CD Track 12) demonstrates the use of arrays in controlling *Looper, Pulse Amp Stereo,* and *2x8 Mixer*. The two channels of *Pulse Amp Stereo* process the audio excerpt from *Looper* using two gradually changing speeds sent by the arrays pictured in Figure 11. The audio channels are then routed through the two channels of *2x8 Mixer*. These two channels are then controlled by another set of arrays. Figures 12 and 13 illustrate the arrays that control the *X pan* parameters of the mixer's two channels.

Fig. 12 - Array storing Channel 1 *xpan* values

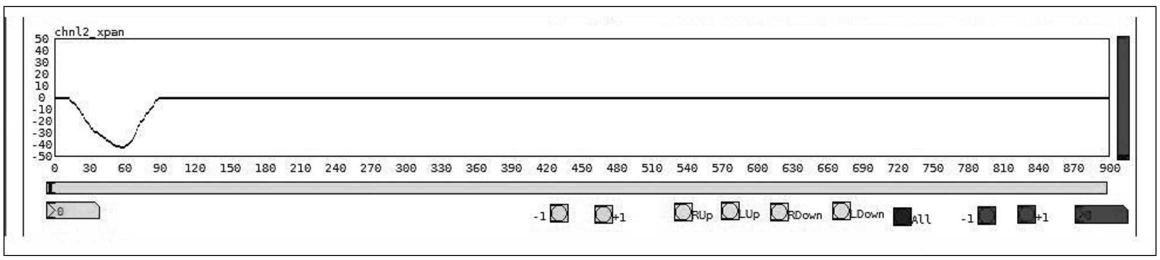


Fig. 13 - Array storing channel 2 *xpan* values

Over the course of the example, channel one gradually increases in modulation speed from 0 to 10 cycles per second while channel two initially sustains 10 cycles per second and gradually decreases to 0. Channel one and two begin in the center then pan outwards to the left and right respectively, and finally return to center by the end of the example.

Sending Array Data to the Software Components

The arrays are similar to musical lines in a score in that they store the musical data that is then sent to the software components in order to be executed over time. This approach makes the overall function of the software components similar to that of a MIDI sequencer in that musical values are stored, edited, and then played back for performance. I have created a simple *Transport* module that allows one to play from selected location times and stop playback. Figure 14 shows the graphic interface for *Transport*. Each array contains an indexed list of 900 values. I refer to this indexed list of values as *tick* numbers. These Ticks are simply numbered events and should not be thought of as elements related to rhythm in that thhey do not affect the listener's perception of time. The transport does not have a record function in that all array editing is done manually through each array's graphic interface.

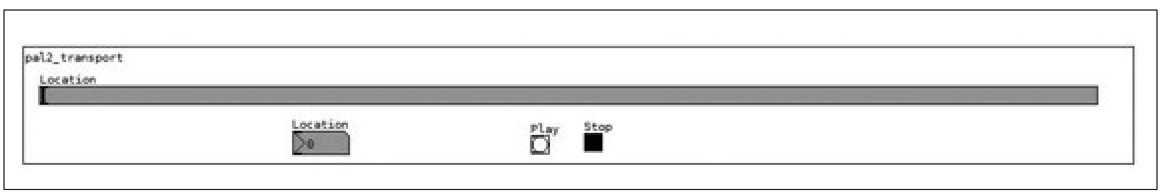


Fig. 14 - The graphic interface of the *Transport* module

The speed at which *Transport* sends array values is controlled by the *Tempo* array. Since the *ticks* measure the storage of events in the array, the *Tempo* array controls the speed at which these events are read. It does not, however, affect the perception of time in the piece and does not govern tempo in the traditional sense. Seeing how the perception of rhythm and time is governed by the effects produced with either *Pulse Amp*

Stereo or *Pulse Amp Quad*, the speed at which the array values are sent to the software components do not affect the listener's perception of rhythm or time. Rather, the speed at which array values are sent to the components governs how fast values change. In this way, the *Tempo* array and the speed at which *ticks* are read govern the progression of form and musical change rather than rhythm. Figure 15 illustrates the *Tempo* array, which allows the speed at which *Transport* reads array values to be changed over time.

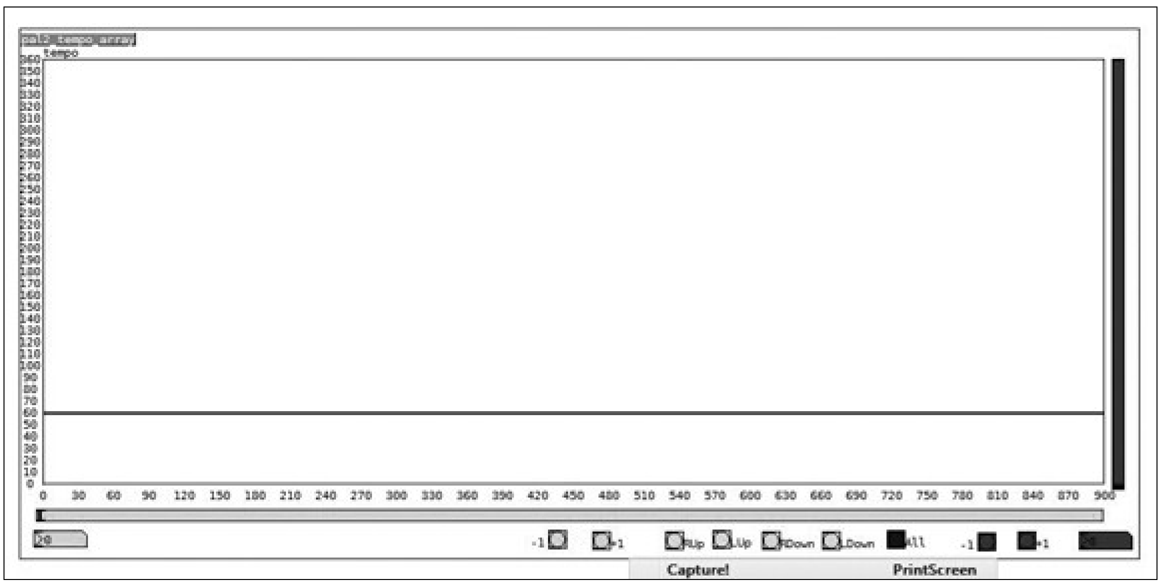


Fig. 15 - The *Tempo* array

Saving the Musical Data and Recording the Audio

In order to combine the software components into an integrated software environment, I have created two different Pure Data patches that combine the different modules into a functional sequencer for compositions. The first patch is entitled *Palsplit 2* and combines all of the modules and arrays that are designed for 2 channel composition. *Palsplit 2* therefore combines *Looper*, *Pulse Amp Stereo*, *Bandsplit 2*, *2x8 Mixer*, and the arrays that store the values for all of these modules. *Palsplit 2* routes the signal from *Looper* into *Bandsplit 2*, where the signal is divided into 2 channels whose frequency ranges are designated by the cut off frequency for the low pass and high pass filters. The signal then proceeds to *Pulse Amp Stereo* where the separate frequency and phase values are applied. Finally, the signals are routed to *2x8 Mixer*, where the two separate channels can be spatially placed by the *xpan* and *ypan* coordinates for each channel.

Palsplit 2 contains three arrays that store values sent to *Looper* which control the on and off setting of the module, the start time of the loop, and the end time of the loop. Four arrays control *Pulse Amp Stereo* by storing the frequency values and phase values for each channel. One array stores the frequency cut off value for *Bandsplit 2*. Finally three arrays are used to control the *amplitude*, *xpan*, and *ypan* settings for channel 1, and a separate group of three arrays are used to store the same three values for channel 2. *Palsplit 2* designates channel 1 as the left channel and channel 2 as the right channel. This designation is not used to define panning since each channel can be panned anywhere throughout the 8 channel spatial field; rather, the designation labels the channels as being graphically displayed on the left and the right side of the graphic interface respectively.

Figure 16 shows the *Menu* module of *Palsplit 2*, which allows the user to store the data contained in the arrays as well as the envelopes used by *Pulse Amp Stereo*. The *Menu* module also stores the file name specification for the audio file used by *Looper* as well as the audio specifications such as sampling rate and number of audio channels (8 channels is used for each movement of the piece).

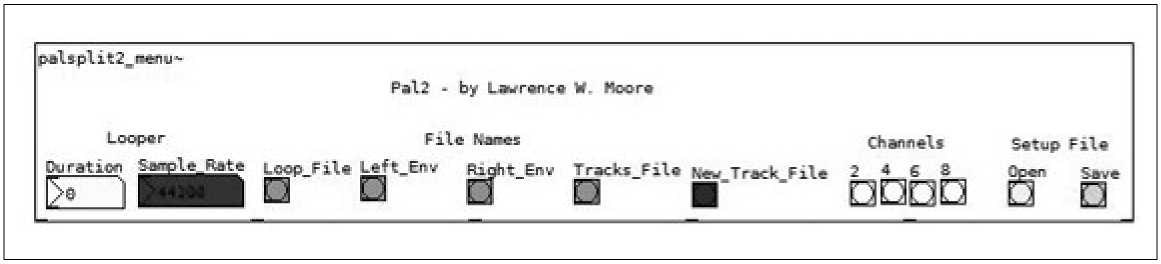


Fig. 16 - The *menu* module for *Palsplit 2*

The second combined patch for 4 channel composition is entitled *Palsplit 4*. It is similar to *Palsplit 2* except it splits *Looper* into 4 signals that are divided into separate frequency ranges by *Bandsplit 4*. The 4 signals are then routed through *Pulse Amp Quad*, which applies frequency and phase processing to the 4 separate channels. Finally, the signals are routed through *4x8 Mixer* where the signals each have their own *amplitude*, *xpan*, and *ypan* settings. *Palsplit 4* uses three arrays for *Looper* as does *Palsplit 2*, but requires more arrays to control the additional values used for the 4 channel processing of the other modules. *Pulse Amp Quad* uses a group of four arrays to control the 4 frequency settings and a separate group of 4 arrays to control the phase settings. *Bandsplit 4* has three arrays to store the 3 frequency values that divide the frequency spectrum into 4 bands. Finally, 4 separate groups of 3 arrays store the *amplitude*, *xpan*, and *ypan* values for the 4 channels of *4x8 Mixer*. Figure 17 illustrates the *Menu* module for *Palsplit 4*.

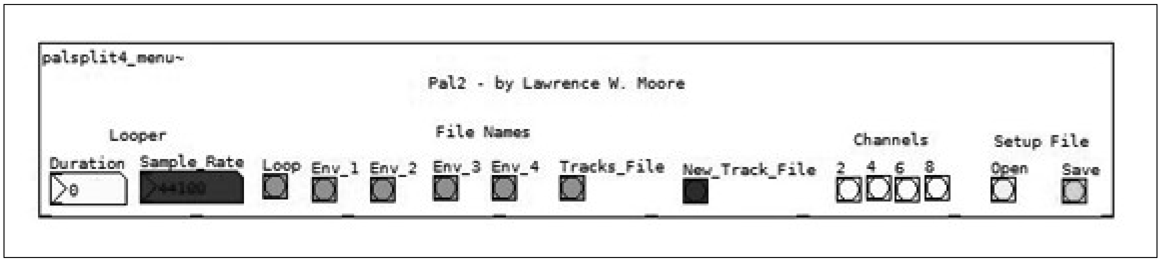


Fig. 17 - The *Menu* module for *Palsplit 4*

Deck is a module that is used in both *Palsplit 2* and *Palsplit 4*. This module provides a master fader for the audio output, on and off controls for the overall audio signal, and a record function. The record function allows one to record the 8 channel audio output from the entire software environment to an interlaced AIFF file. This file can then be played back using just about any multi-channel audio sequencing software for performance. Figure 18 illustrates the *Deck* module.

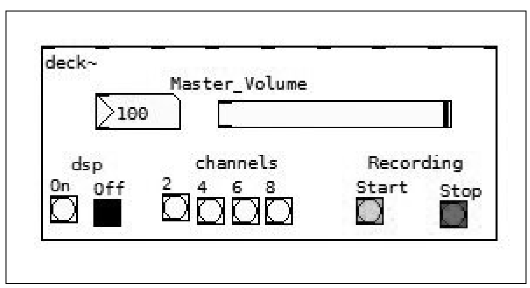


Fig. 18 - The *Deck* module

CHAPTER III

COMPARISON AND CONTRAST WITH OTHER WORKS

The aforementioned pieces, *Come Out* by Steve Reich and *I am Sitting in a Room* by Alvin Lucier, were inspirations for the undertaking of this work. In order to evaluate the significance of *Hawking Sonified* and to compare and contrast it with similar works, I have also researched other pieces that employ the processing of recorded speech as the primary approach. The article *Voices from the Past: Compositional Approaches to Using Recorded Speech* by Cathy Lane[7] documents the history of compositions that utilize recorded speech as well as categorizes the specific approaches used in the recording of the pieces. In her article, Lane specifies a category for music that strives to enhance the meaning within the text which she calls "Accumulation of Meaning by Structured Association." She further describes this category by stating that "Meaning is reinforced by the way that text is manipulated and structured." While I examined pieces outside of this category as well, I began by examining pieces within this category as they are most related to the intention of *Hawking Sonified*.

The only example that Lane gives in this category is the piece *Geekspeak* by Pamela Z[8]. The piece is a recitation of personal thoughts, seemingly from a diary by a narrator. These thoughts are enhanced by a male voice that expresses fearful and paranoid ideas related to the narrated text. The processing that is applied to the piece is

[7] Cathy Lane, "Voices from the Past: Compositional Approaches to Using Recorded Speech," *Organized Sound* 1, no. 1 (April 2008): 3-11.

[8] Pamela Z., "Geekspeak," *Delay is Better*, Starkind B0002UUF5I, 2004, CD.

primarily the timing of entrance from the male voice and the clustering of phrases. *Hawking Sonified* is quite different in that it utilizes an archival recording of lecture excerpts and outlines these ideas without any added material, but rather through processing alone. Additionally, the processing is based on rhythmic patterns and spatial manipulation as opposed to layering and timing of entrances.

Outside of Lane's category, I investigated other works that seemed to bear relevance. *Two Women* by Trevor Wishart[9] utilizes archival recordings of Margaret Thatcher, Princess Diana, and the preacher, Ian Presley (one of the leaders of the protestant movement in Northern Ireland during the recent unrest). The piece also includes sounds from a train station. Wishart uses a variety of processing in the piece in order to enhance the meaning of lines of text. In Wishart's piece, the selection of the text and processing of the speech recordings are processed to fit the composer's form. Another difference is that the piece is more focused on timbre and does not employ rhythmic pulsing or pulse patterns as a significant part of its composition.

Lane's article also addresses the Steve Reich piece, *It's Gonna Rain*[10]. This piece is similar in nature to *Come Out* in that the majority of the piece is composed of a loop of short duration audio phasing employed as the chief method for establishing gradually changing rhythmic patterns. In *Hawking Sonified*, I am looping larger sections of speech and the rhythmic pulsing effects are utilized to sonically illustrate the meaning within the lecture excerpts. Reich's use of rhythmic patterns in *It's Gonna Rain* and *Come Out* do not strive to illustrate the meaning within the text, but are serendipitous.

[9] Trevor Wishart, "Two women," *Voiceprints*, EMF EM129, 2000, CD.

[10] Steve Reich, "It's Gonna Rain," *Early Works*, Nonsuch 1242768, 1992, CD.

Another composer who has made significant contributions to music based on voice sampling is Paul Lansky. Lansky has composed several works that utilize recorded speech and processing. One such piece, *Smalltalk*[11] has been analyzed by Brent Reddy[12]. Reddy discusses the compositional process as well as the structure of the piece. The voice material was recorded from a half-hour conversation between Lansky and his wife, Hannah MacKay. The processing of the speech was achieved through the use of Lansky's own software, which he developed specifically for the piece. The processing renders the words unintelligible. Lansky likens his approach to enlarging a digital photo to the point where the individual pixels become so big that the picture is no longer recognizable. Lansky also uses pitch shifting in order to create modal key centers for the piece. Reddy's article defines the modes utilized in each section. The voice samples trigger the generation of short duration tones and long duration pads that help build triadic harmonic structures on the pitch material in the recorded spoken voices.

On the album, *More than Idle Chatter*[13], Lansky presents three similar pieces entitled *Idle Chatter*, *Just_More_Idle_Chatter*, and *Notjustmoreidlechatter*. All three pieces use material derived from voice recordings of Hannah MacKay. The audio clips are cut up into such small pieces that complete words are difficult to discern. According to the liner notes, a textual meaning is not intended. The short clips are arranged into rhythmic figures and patterns that Lansky uses like instruments. Each of the three pieces

---

[11] Paul Lansky, "Smalltalk," *Smalltalk*, Albion B000000R2Q, 1994, CD.

[12] Brent Reddy, "Lansky's Smalltalk," *Musikwisenbloggenschaft*, July 16, 2008, http://musikwissenbloggenschaft.blogspot.com/2008/07/lanskys-smalltalk.html. (accessed March, 2009).

[13] Paul Lansky, *More then idle Chatter*, Bridge Recordings B000003GJ8, 1994, CD.

has a different aesthetic and musical outcome, but are all created in the same manner. Lansky indicates in the liner notes that they are not meant to be listened to one after the other, and for this reason, he did not program them consecutively on the album. The similarity in approach between the three pieces makes them sound as if they were performed by the same "ensemble." While these pieces utilize rhythm as a significant element in their sound, though none of the pieces utilize gradual process as an approach as does *Hawking Sonified*.

CHAPTER IV

MOVEMENT I

The first movement of the piece uses the lecture excerpt on entropy, which is recorded in its entirety in Audio Example 13 (Audio CD Track 13). The excerpt describes entropy by proposing an analogy that involves a box containing oxygen molecules on one side and nitrogen molecules on the other with a dividing wall between the two sides. The analogy describes the process of entropy by indicating that if the dividing wall is removed, the molecules begin to mix. The first movement illustrates this analogy through a gradual process that evolves from the early separated state to the ending mixed state. Figure 19 depicts the early state on the left and the ending state on the right. The light grey box on the left side shows how the left channel has a low frequency pulse rate signifying nitrogen molecules. The right side of the spatial field symbolizes the oxygen molecules by using a higher frequency setting for the rhythmic pulsing. Over the course of the piece, the two contrasting pulse patterns mix across the spatial field.

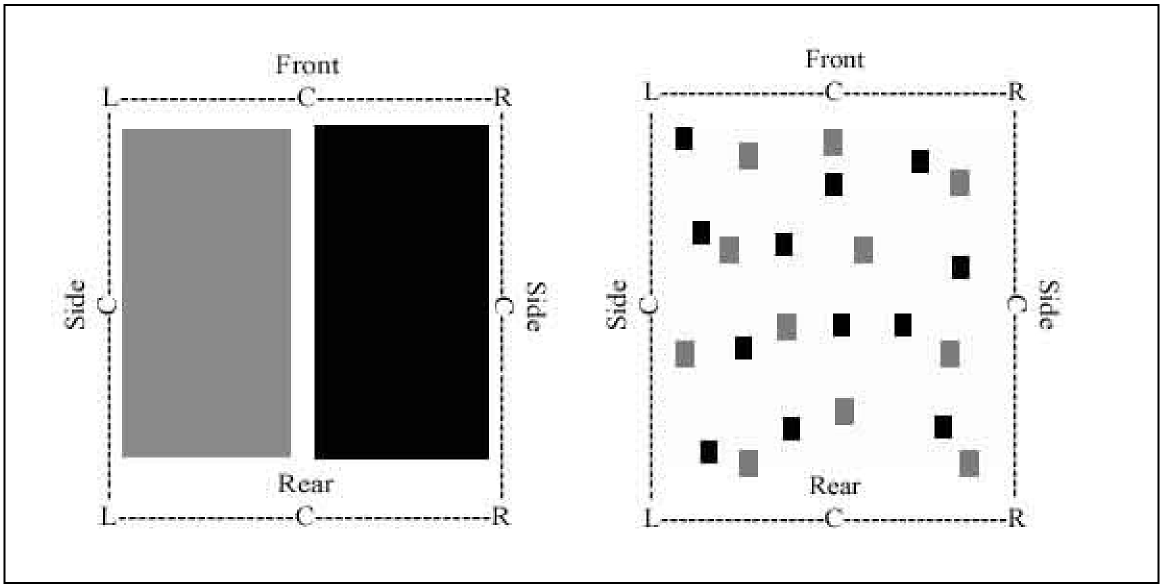


Fig. 19 - Illustration of the process in Movement I

Movement I uses *Palsplit 2* because the representation of the oxygen and nitrogen molecules is achieved using two separate channels of audio signal. The left channel represents the oxygen molecules while the right channel represents nitrogen. Being the heavier of the two elements, oxygen is musically represented using the lower half of the frequency spectrum in *Bandsplit 2*. The frequency spectrum is cut into two bands at 1,000 Hz. Being the 8th element in the periodic table of the elements, oxygen is also characterized by an 80 Hz pulse frequency in *Pulse Amp Stereo*. Nitrogen is similarly represented using the higher half of the frequency spectrum and a 70 HZ pulse frequency in *Pulse Amp Stereo* to signify its being the 7th element in the periodic table. The left and right channels gradually reach their respective values of 80 Hz and 70 Hz during the beginning of the movement in order to create a sense of gradual process for the introduction and an intriguing juxtaposition of the two increasing pulse speeds. Figure 20 shows the arrays containing the *Pulse Amp Stereo* frequency values for the left and right channels.

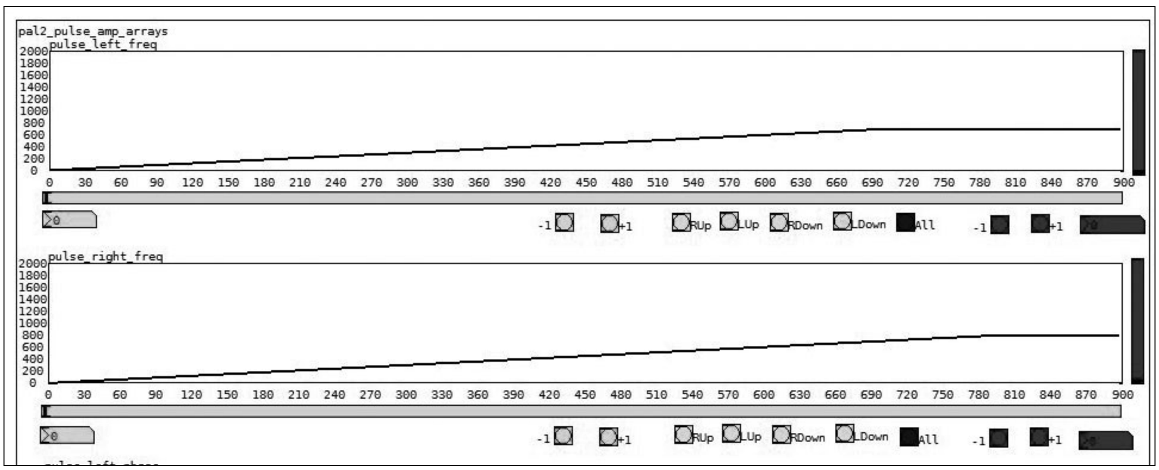


Fig. 20 - *Pulse Amp Stereo* frequency arrays for Movement I

The gradual rise to 80 Hz and 70 Hz of the left and right channels also creates sparseness for the introduction. The sparseness consists of short, spread-out entrances of the lecture text. The gradually increasing frequency values in *Pulse Amp Stereo* slowly bring in longer and more continuous instances of spoken words, thus gradually making the text clearer to the listener. In order to accentuate the sparseness at the beginning, I created a triangular shaped envelop that is used by both channels in *Pulse Amp Stereo*. Figure 21 shows the two envelopes in the *Pulse Amp Stereo* module.

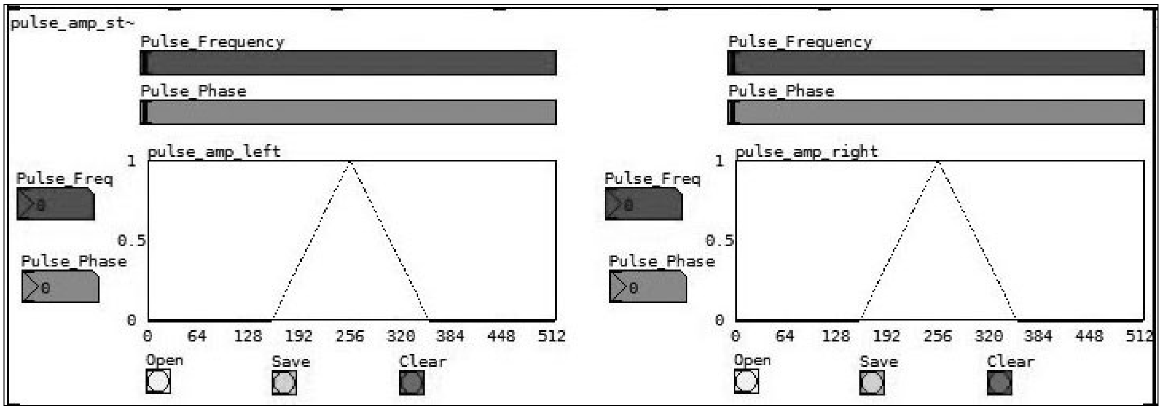


Fig. 21 - The amplitude envelopes used by *Pulse Amp Stereo* in Movement I

The frequency values rise to 80 Hz and 70 Hz approximately 75 percent of the way through the length of the arrays. This is because the frequency values for each array are increased incrementally to create a smooth increase in the frequency of the amplitude pulsing. Seeing how the musical meaning of the movement is only achieved when the left and right channels reach their stabilized pulse frequencies of 80 Hz and 70 Hz, I have shortened the duration of the introduction and extended the duration of the movement beyond *tick* 750. I accomplished this by setting the *Tempo* array value at 900 *ticks* per minute up until *tick* 750 and 360 *ticks* per minute from *tick* 750 until the end. In this way, the introduction and the main part of the movement are proportionally balanced in terms of formal duration. Figure 22 illustrate the *Tempo* array for Movement I.

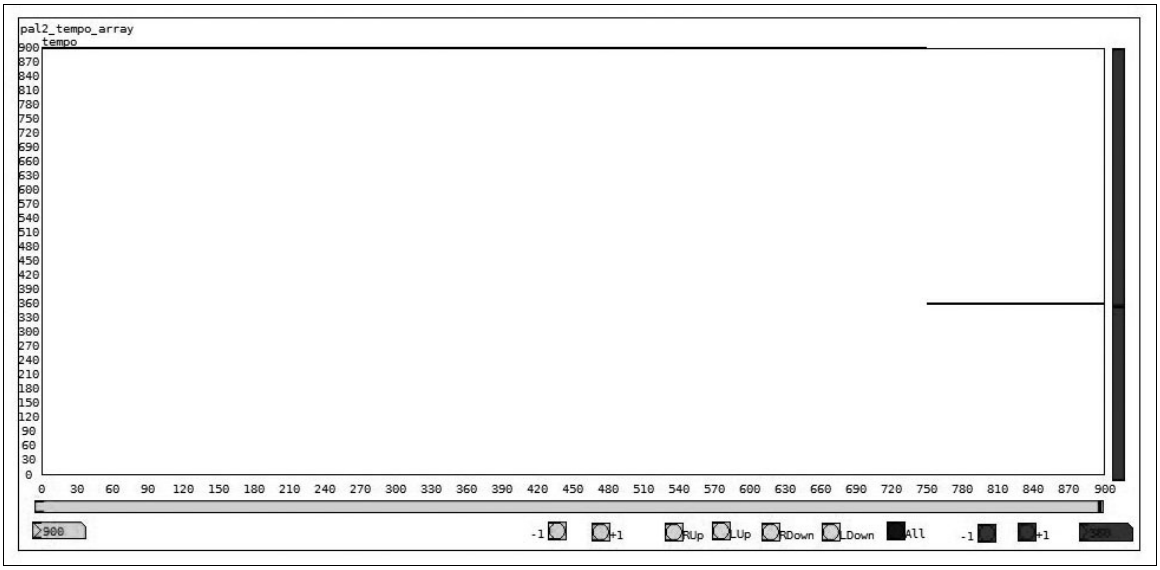


Fig. 22 - The *Tempo* array for Movement I

At *tick* 750, the musical illustration of the mixing molecules begins to take place. Up until this point he only panning that takes place is between the front and back as the left and right channels are maintained separated to the far left and far right of the spatial field. The front to back panning is to create more musical interest in that a completely static position of the signals seemed to lack musical development in my compositional opinion. Furthermore the front to back panning does illustrate that gaseous molecules do tend to move even when contained. At *tick 750*, the mixing of the oxygen and nitrogen molecules begins musically as the 80 Hz low frequency audio signal gradually blends with the 70 Hz high frequency signal. At this point, the listener has heard full repetitions of the lecture excerpt such that he or she understands the meaning of the example and can relate it to the music. This blending of the different pulse rates and frequency bands also creates juxtapositions that overlap spatially. Figures 23 and 24 show the *2x8 Mixer* arrays that store the values for spatial placement (*xpan* and *ypan*).

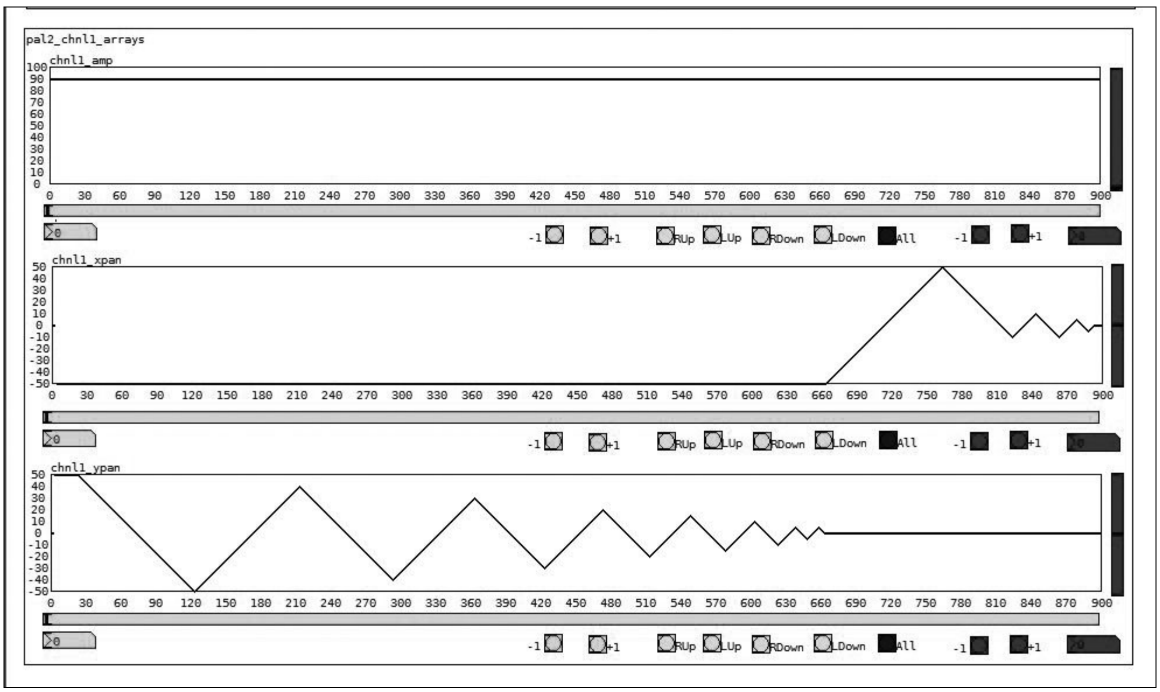


Fig. 23 - The arrays for channel 1's mixer settings

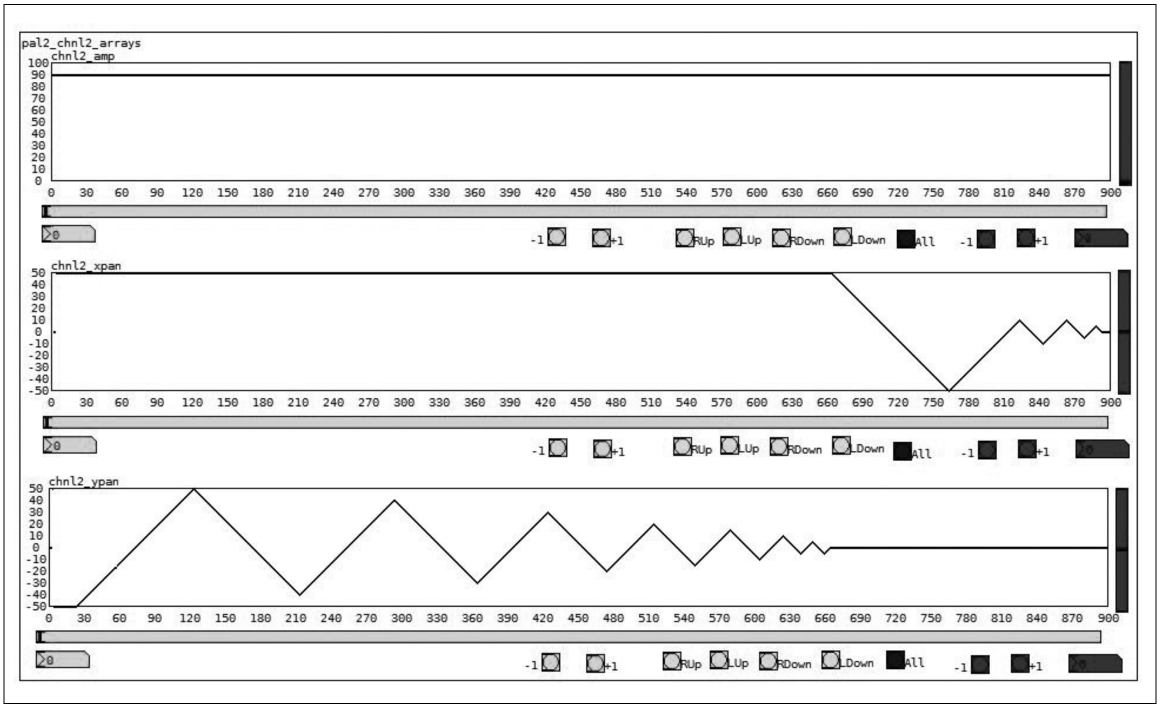


Fig. 24 - The arrays for channel 2's mixer settings

Audio Example 14 (Audio CD Track 14) is a stereo recording of the first movement. The stereo recording is not a definitive recording, however, and is only provided for convenience. Only the 8 channel recording provides the true effect of the spatial placement of the movement. The included Data CD provides the multi-channel AIFF file for the performance of this movement.

CHAPTER V

MOVEMENT II

The second movement is based on a lecture concerning the event horizon of a black hole. The lecture describes a scenario in which signals are sent from an astronaut that is standing on a star that is shrinking to the state of becoming a black hole. The astronaut sends signals on each minute between the times of 11:00pm and midnight. The lecture describes how toward the end of the hour, the signals from the astronaut would become delayed, and the last signal at midnight, however, never leaves the black hole because, at that point, gravity becomes so strong that the signal can no longer escape its gravitational pull. The full length recording of this lecture excerpt is Audio Example 15 (Audio CD Track 15).

The audio file for the second movement has 7 sets of loop points. Each set of loop points is a separate set of start and end times for *Looper*. These separate segments are looped at equal durations throughout the movement. These loops are analogous to the signals sent by the astronaut as the 12:00 hour approaches. Figure 25 shows the arrays for *Looper* which store the start and end times for each looped segment.

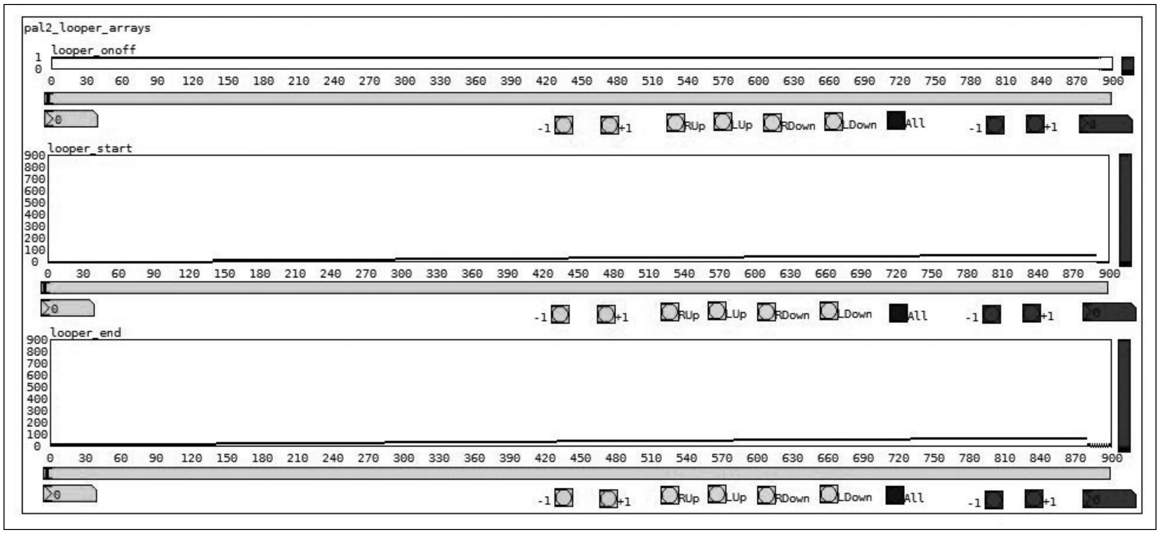


Fig. 25 - The *Looper* arrays for Movement II

In order to create the sense of movement for the astronaut's signal, the audio loops are panned from front to back over the duration of each of the 7 segments. Additionally, the two audio channels in *Palsplit 2* are set in juxtaposition to one another as they are panned from center to hard left and hard right respectively. This effect also helps to create a sense of musical motion within the steady front to back motion that is illustrating the lecture. Figure 26 shows the arrays for the left channel signal of *Palsplit 2* and Figure 27 shows the right channel arrays.

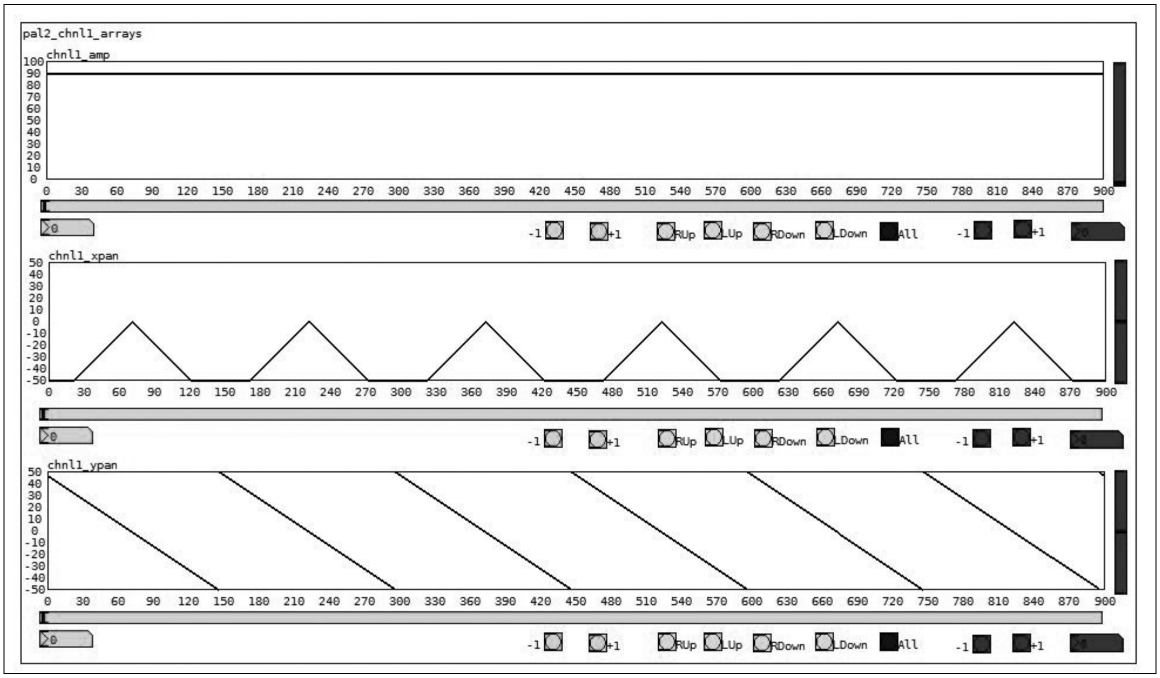


Fig. 26 - The left channel arrays for Movement II

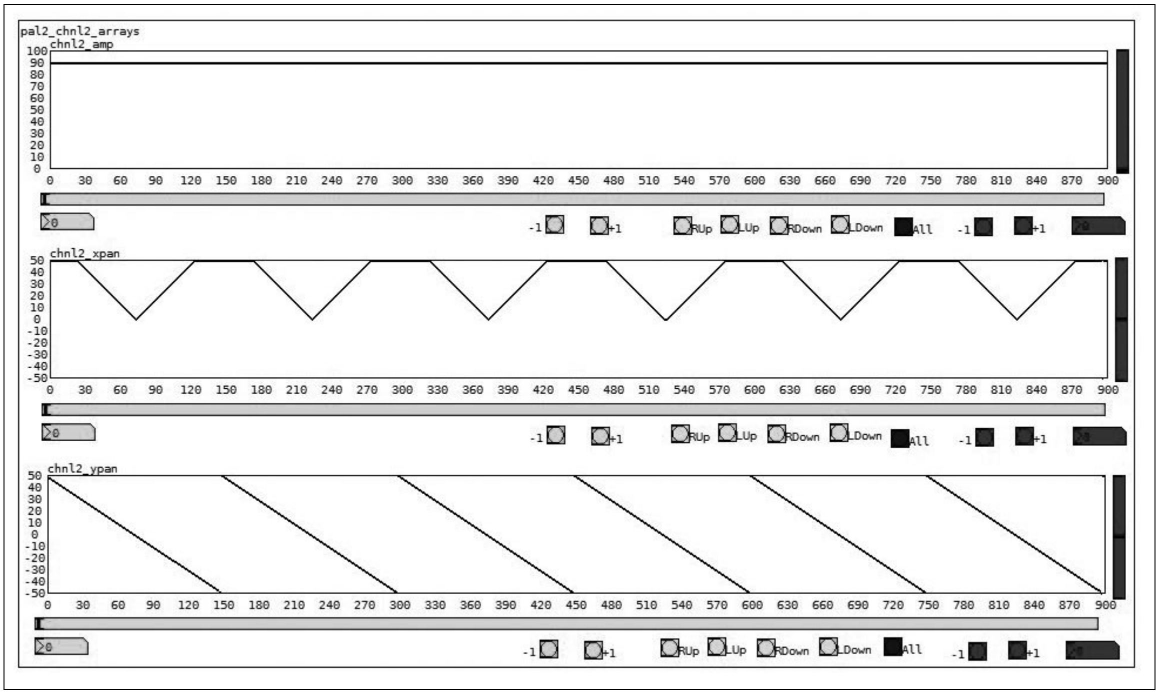


Fig. 27 - The right channel arrays for Movement II

Over the duration of the movement, the frequency values of *Pulse Amp Stereo* are gradually decreased. This is done to represent the slowing of time as the astronaut's signals try to escape the dying star. The two channels are descending in parallel motion, but throughout different ranges in order to create rhythmic interplay between the two signals. Each channel uses the same cosine envelope that was pictured in Figures 1 and 2. Figure 28 shows the *Pulse Amp Stereo* frequency arrays for the two channels.

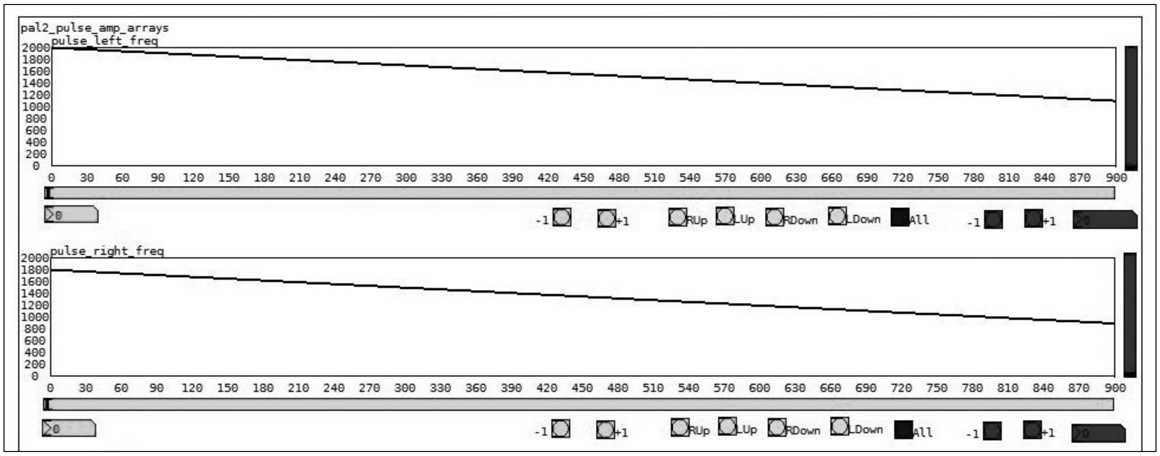


Fig. 28 - *Pulse Amp Stereo* frequency arrays for Movement II

Audio Example 16 (Audio CD Track 16) is a stereo rendering of Movement II. As with the first movement, the definitive, 8 channel version is on the included Data CD.

CHAPTER VI

MOVEMENT III

The lecture recording for the third movement, Audio Example 17 (Audio CD Track 17), concerns the theoretical concept of imaginary time and what would be the result of the cosmos' lifespan if imaginary time held true. As the lecture indicates, imaginary time would present a situation in which the cosmos would expand from a singularity until a contracting phase would begin in which it would shrink back into a singularity once again. This same process would then repeat over and over again. In order to represent this construct spatially, the third movement would use both *xpan* and *ypan* to expand and contract the overall sound field in outward directions. Figure 29 illustrates this concept in comparing the starting point of a singularity on the left side of the diagram and the expanded phases on the right side of the diagram.

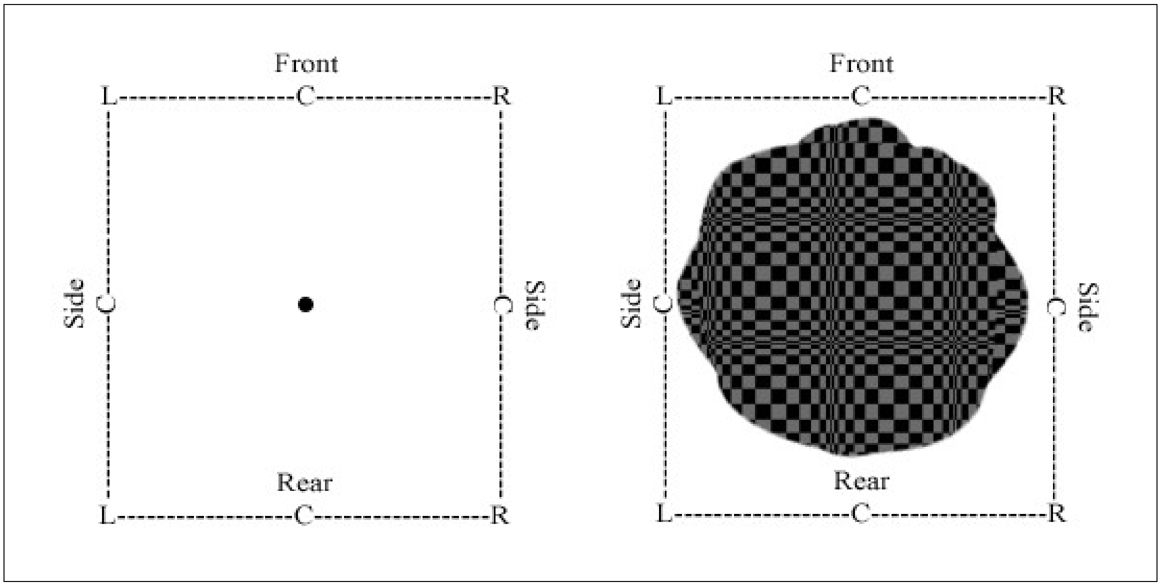


Fig. 29 - Example of the contracted and expanded spatial field in Movement III

Movement III uses *Palsplit 4* and has 4 discrete audio signals. These signals have their own spatial plotting that expands outward from a central location to create the effect of expansion. During the three expansion phases, the four channels move in different directions from the center point to the four corners of the spatial field (front left, front right, rear left, and rear right). Due to the proximity panning, sound does emanate from all 8 speakers, but the listener expresses the outward expansion as strongest in the aforementioned corner speakers. Figures 30 – 33 illustrate the array values and panning motions for the four different audio channels.

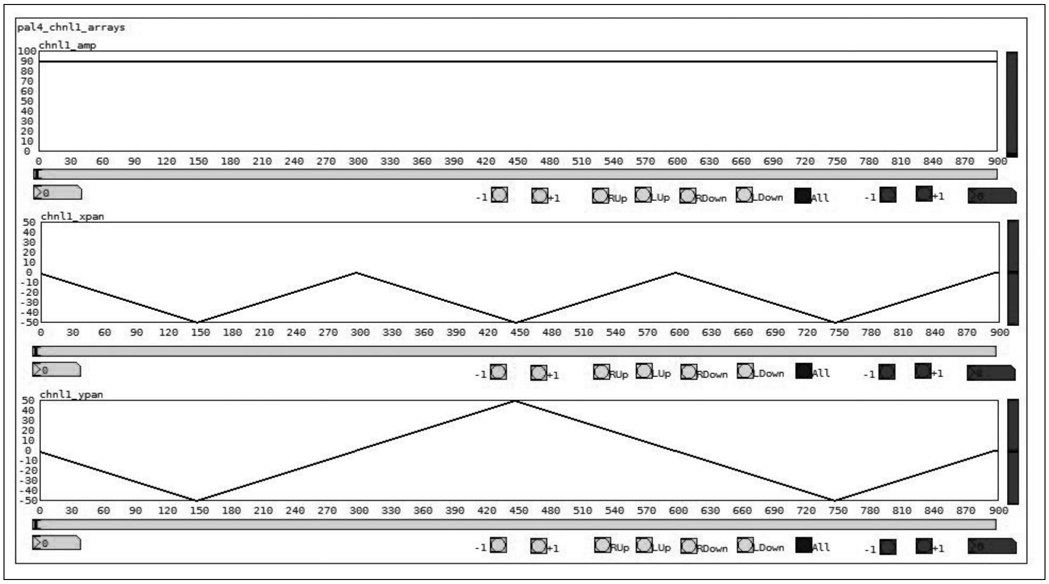
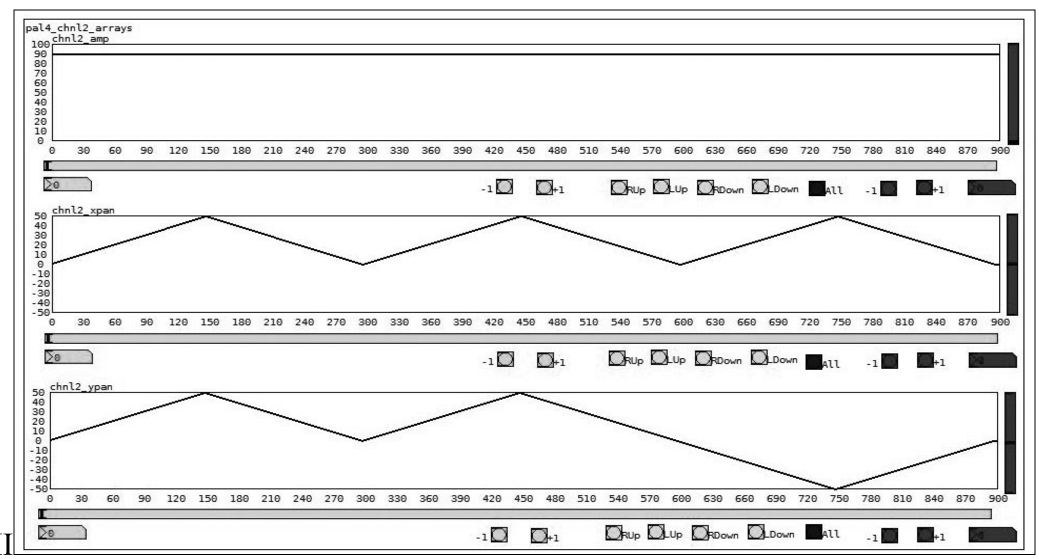


Fig. 30 - Channel 1 mixer arrays for Movement



III

Fig. 31 - Channel 2 mixer arrays for Movement III

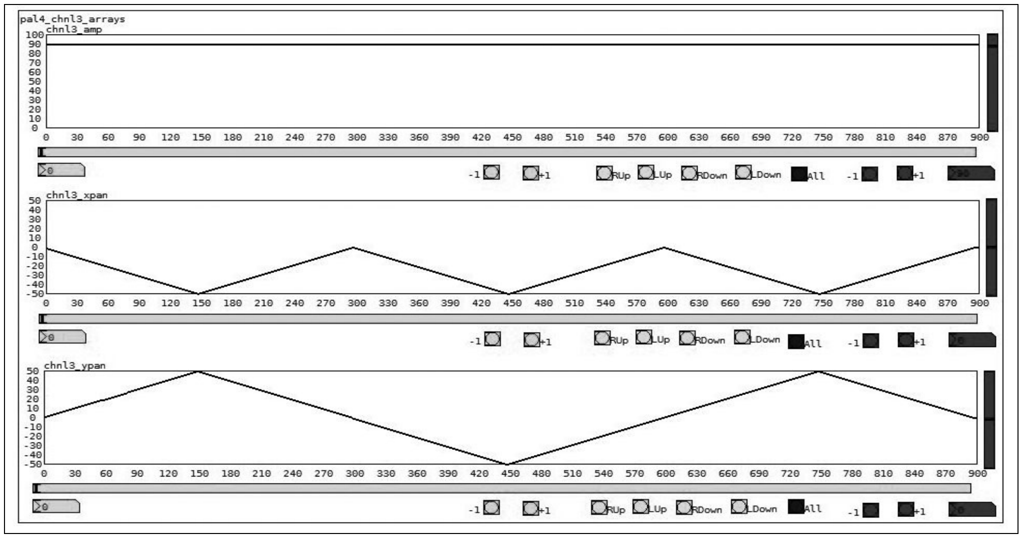


Fig. 32 - Channel 3 mixer arrays for Movement III

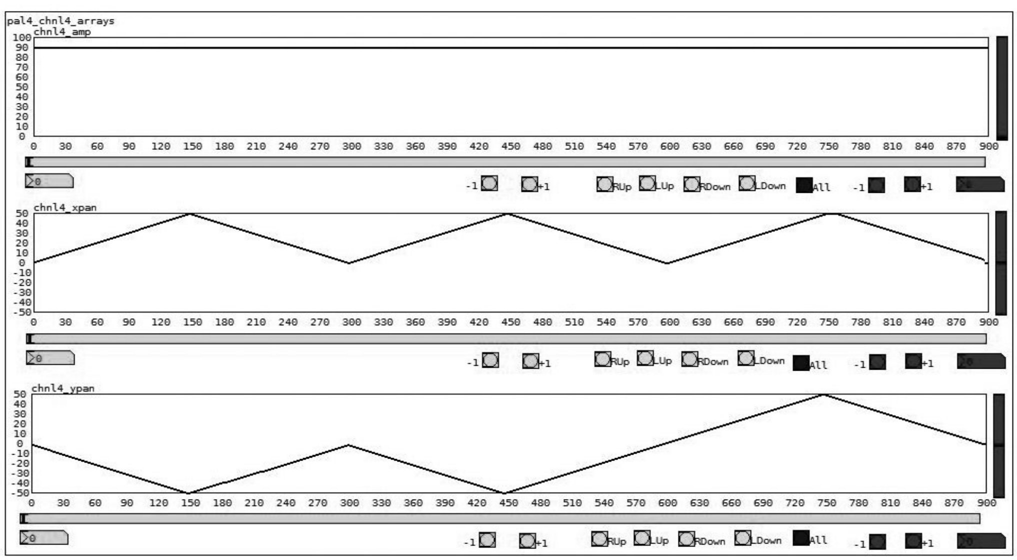


Fig. 33 - Channel 4 mixer arrays for Movement III

The 4 channels have unique amplitude envelopes and are routed through *Bandsplit 4* for discrete frequency bands to be associated with each channel. Channel 1 goes through a low pass filter set at 800 Hz. Channel 2 has a frequency range of 800 Hz to 1,000 Hz. Channel 3 is routed through a band pass filter that is set to 1,000 Hz at its bottom and 1,800 Hz at its top. Channel 4 is routed through a high pass filter which is cut off is set at 1,800 Hz. These settings divide, fairly evenly, the frequency range that Hawking's voice occupies. The frequency settings do not change over the duration of the movement. Figure 34 illustrates the amplitude envelopes assigned to each channel.

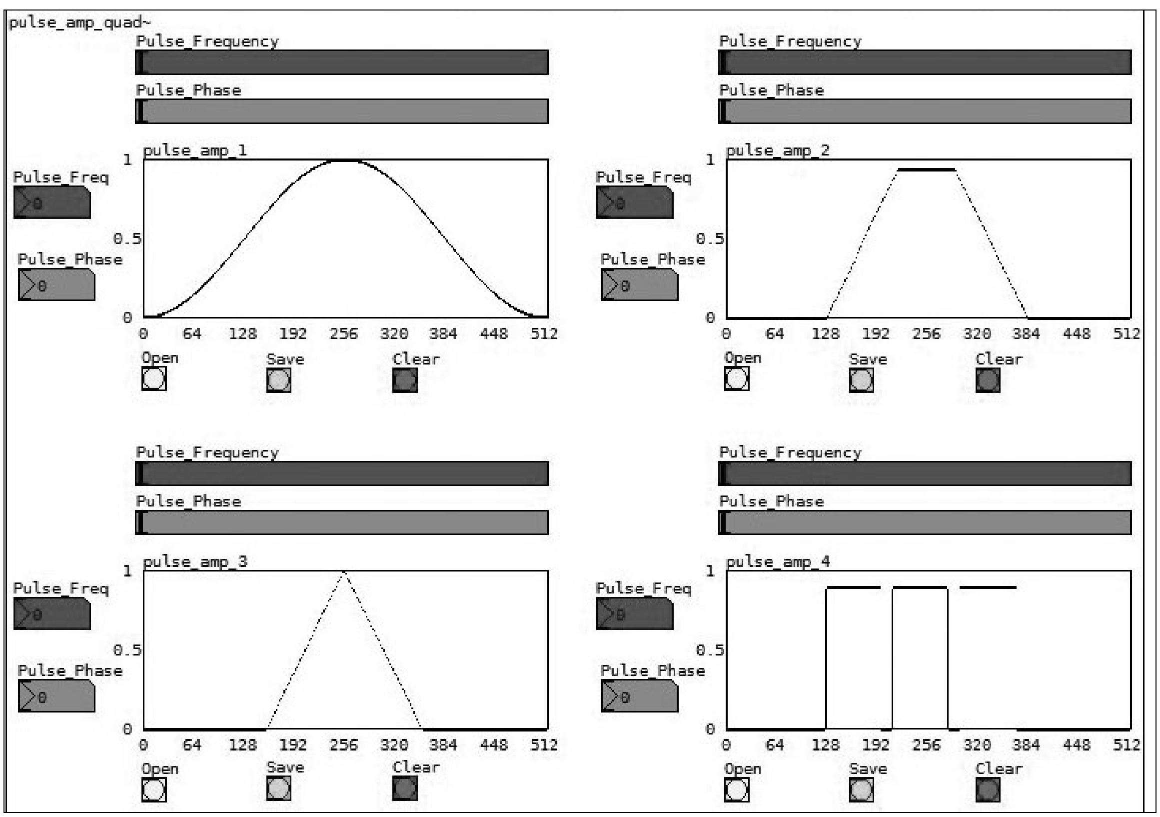


Fig. 34 - The amplitude envelopes used by *Pulse Amp Quad* in Movement III

Each channel has an arc-shaped curve that defines a linear change in pulse frequency for the three segments of the movement. The arc shape is intended to highlight the expansion and contraction of the cosmos in that the frequency settings of each channel start at a specific value then rise or descend from that value only to return to the starting value again. These changing values are set in juxtaposition to one another between the 4 channels. Figure 35 shows the arrays for channels 1 and 2, and Figure 36 shows the arrays for channels 3 and 4.

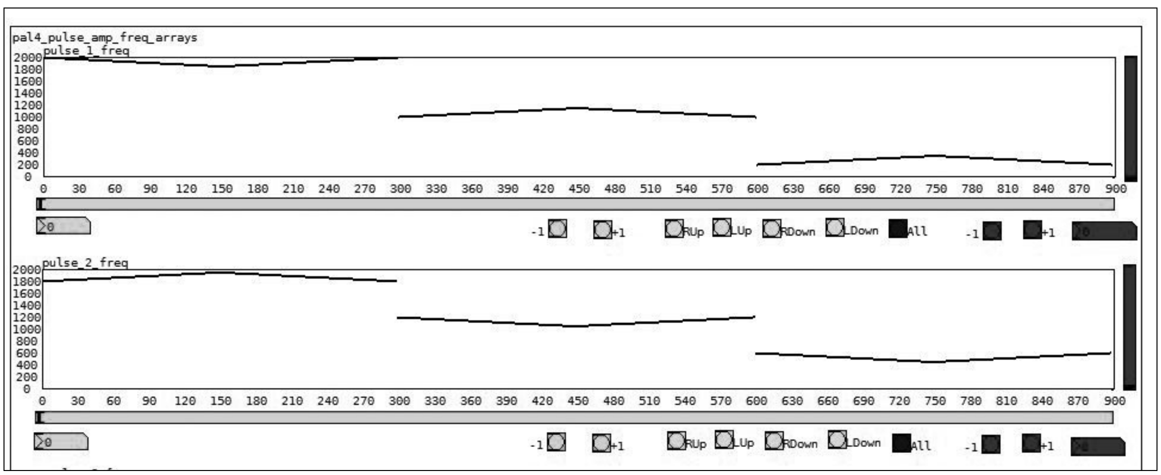


Fig. 35 - Pulse frequency arrays for channels 1 and 2 in Movement III

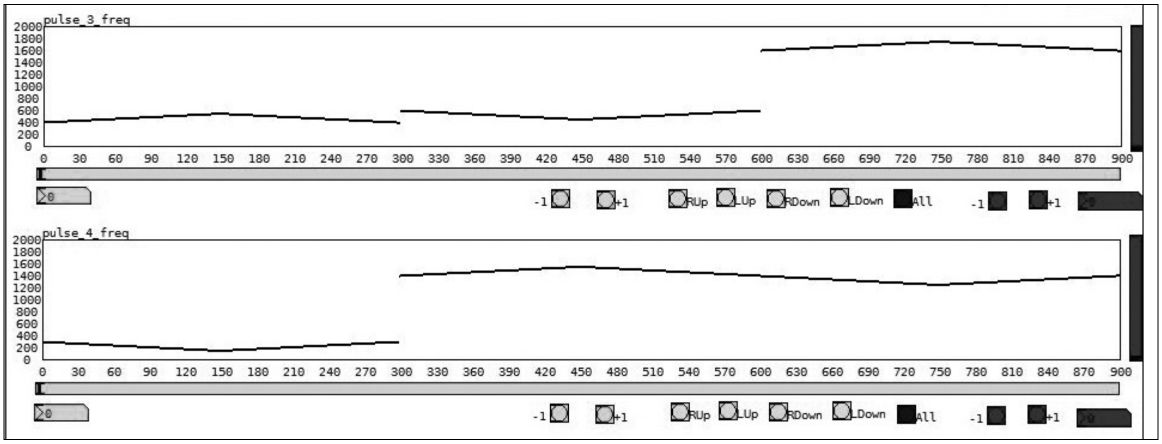


Fig. 36 - Pulse frequency arrays for channels 3 and 4 in Movement III

Audio Example 18 (Audio CD Track 18) is a stereo version of Movement III, which is provided for convenience. The full effect of the outward spatial movements is best heard in the 8 channel version that is provided on the included Data CD.

CHAPTER VII

MOVEMENT IV

The fourth movement contrasts with the third movement in that the subject of the lecture recording is real time. In the case of theoretical real time, the life of the cosmos begins with the singularity and either continues to expand or it will contract to end the life of the cosmos without a new beginning. In either case, the life of the cosmos has a definite beginning and end unlike imaginary time. Movement IV uses *Palsplit 4* with the same amplitude envelopes and *Bandsplit 4* settings as the third movement. In this way, Movement IV illustrates a different usage of the same "instrumental" material in order to give a different perspective on similar subject matter.

The spatial movement in Movement IV is comprised of one single outward expansion and contraction over the duration of the movement. Because the movement has one instance of expansion and contraction, it characterizes the subject matter as having a definite beginning and end in the case of a contracting universe that has come to an end. Figures 37 – 40 illustrate the *4x8 Mixer* arrays for Movement IV.

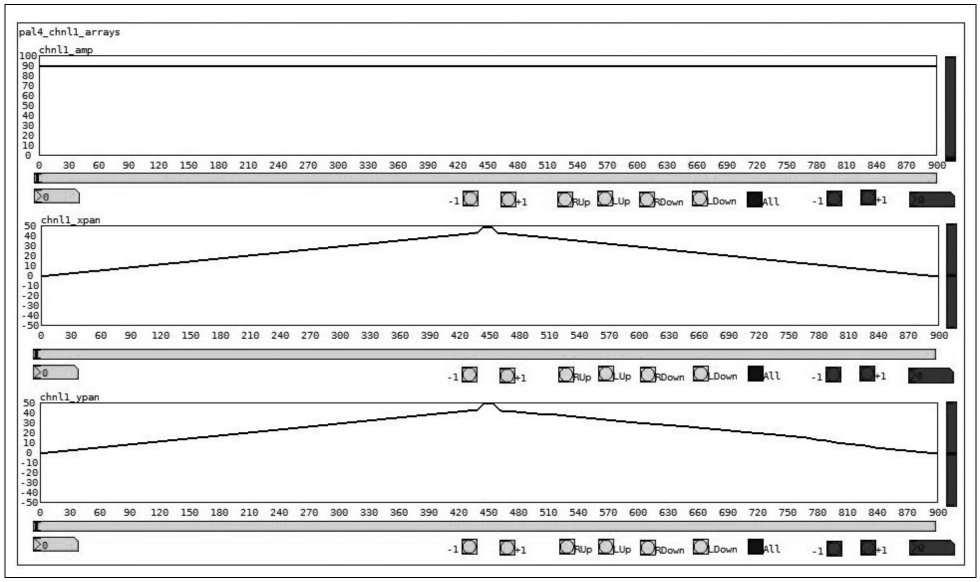


Fig. 37 - Channel 1 mixer arrays for Movement IV

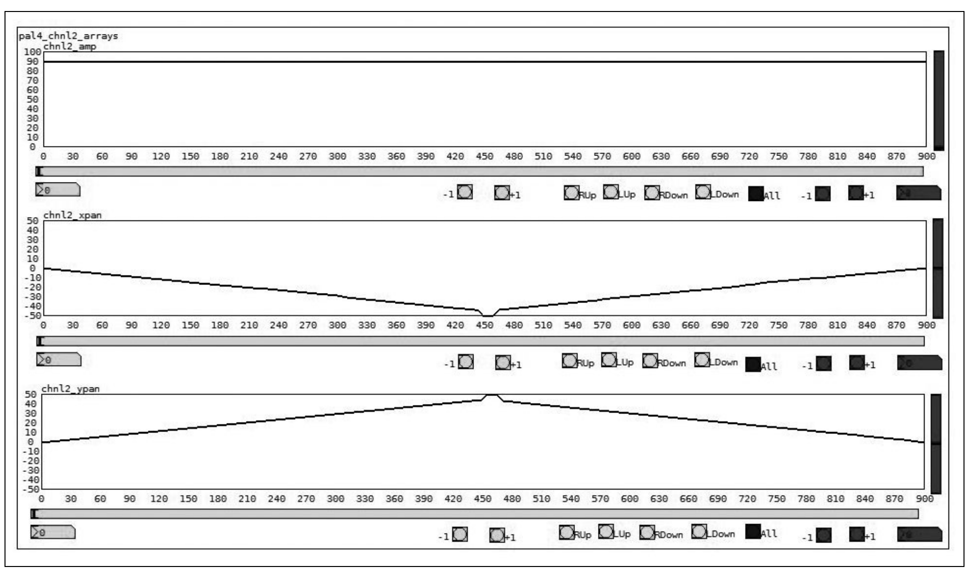


Fig. 38 - Channel 2 mixer arrays for Movement IV

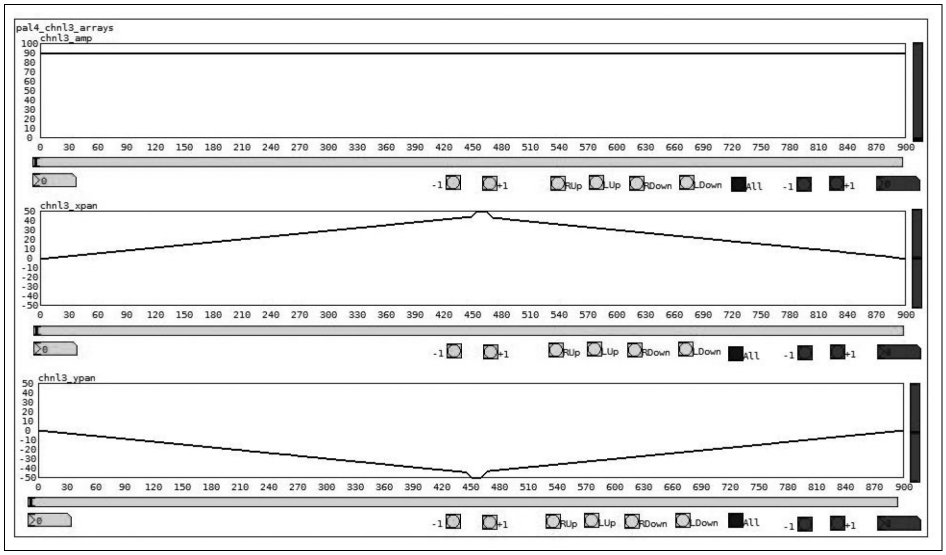


Fig. 39 - Channel 3 mixer arrays for Movement IV

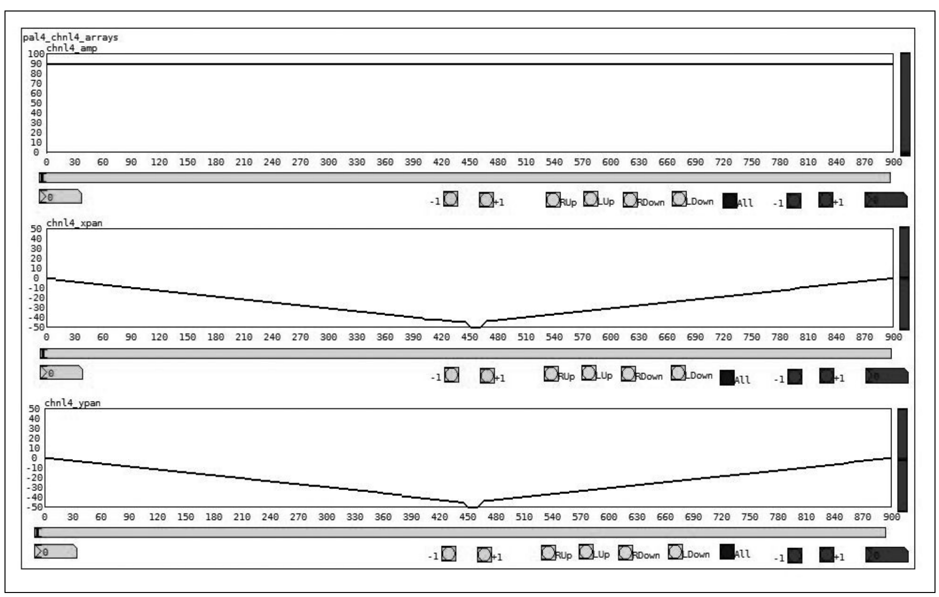


Fig. 40 - Channel 4 mixer arrays for Movement IV

The usage of the pulse frequency in *Pulse Amp Quad*, however, contrasts that of the spatial movement. In this case, each channel's pulse frequency changes in a gradual process from a starting value to an ending value in a linear progression. This use of a gradual process is intended to create a sense of history not repeating itself. The contraction in spatial positioning at the end, therefore does not mirror the expansion, but rather, consist of different musical material. Figure 41 shows the pulse frequency arrays of channels 1 and 2, and Figure 42 shows the pulse frequency arrays for channels 3 and 4.

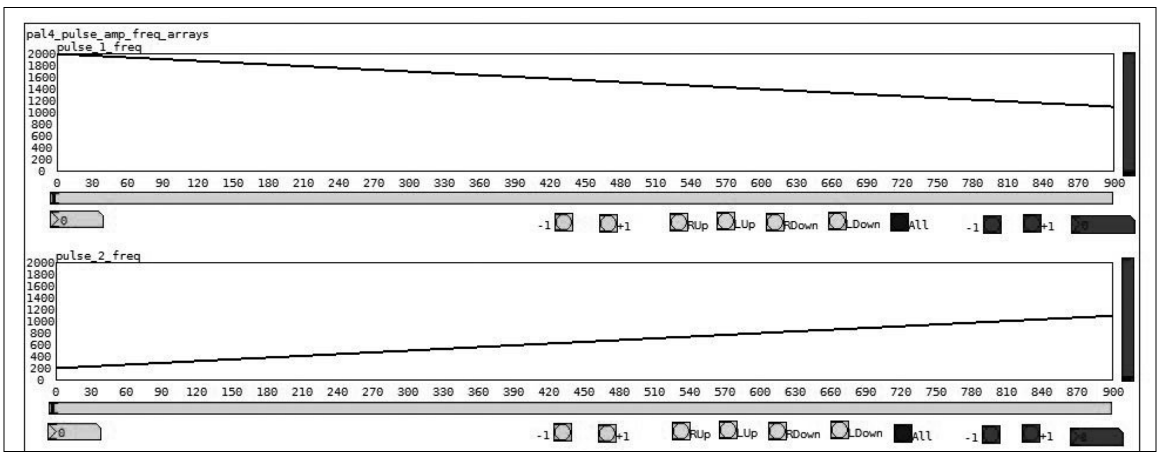


Fig. 41 - Pulse frequency arrays for channels 1 and 2 in Movement IV

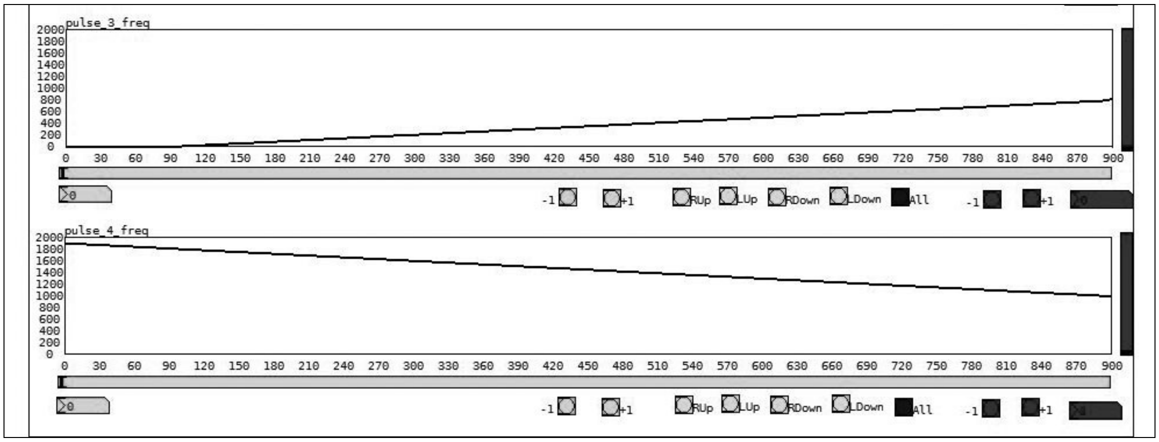


Fig. 42 - Pulse frequency arrays for channels 3 and 4 in Movement IV

As with the previous movements, the stereo version of Movement IV is provided in Audio Example 19 (Audio CD Track 19). Likewise, the definitive 8 channel version is provided on the Data CD.

WORKS CITED

Lansky, Paul. *More then idle Chatter*. Bridge Recordings B000003GJ8, 1994. CD.

Reddy, Brent. "Lansky's Smalltalk." *Musikwisenbloggenschaft*, July 16, 2008. http://musikwissenbloggenschaft.blogspot.com/2008/07/lanskys-smalltalk.html. (accessed March, 2009).

Lansky, Paul. "Smalltalk." *Smalltalk*. Albion B000000R2Q, 1994. CD.

Reich, Steve. "It's Gonna Rain." *Early Works*. Nonsuch 1242768, 1992. CD.

Wishart, Trevor. "Two women." *Voiceprints*. EMF EM129, 2000. CD.

Z., Pamela. "Geekspeak." *Delay is Better*. Starkind B0002UUF5I, 2004. CD.

Lane, Cathy. "Voices from the Past: Compositional Approaches to Using Recorded Speech." *Organized Sound* 1, no. 1 (April 2008): 3-11.

Pure Data 0.39. Miller Puckette, La Jolla, CA, 1999.

Hawking, Stephen. *The Life Works of Stephen W. Hawking: Cambridge Lectures*. New York: Audio Literature, 1996. Cassette.

___. *The Universe in a Nutshell*. New York: Bantam, 2001.

___. *A Brief History of Time*. New York: Bantam, 1988.

Lucier, Alvin. "I am Sitting in a Room." *I am Sitting in a Room*. Lovely Music B00000INI7, 1990. CD.

Reich, Steve. *Early Works*. Nonsuch 1242768, 1992. CD.