MICROTONAL HARMONIC SYSTEMS IN "HARMONIC COLOUR FIELDS" (1996-1997)

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Abstract:

"Harmonic Colour Fields" (1996-1997) is a set of five computer pieces which explore static microtonal harmonic fields using a variety of algorithmic and permutational pitch and rhythm selection methods. The pieces are descended from the 1970s "drone" pieces of such composers as La Monte Young, Charlemagne Palestine, Hal Budd and myself, but they make greater use of slow harmonic progressions to make more varied musical surfaces.

The first, "Portrait of Erv Wilson," uses harmonics based on the Farey Series (order 11), an arithmetic series whose musical uses have been explored by Harry Partch, Ervin Wilson, Rudolf Rasch and Barbara Hero, among others, and which results in an 11-limit just intonation. The second, "Portrait of John Chalmers," explores all the possible tritriadic harmonic combinations available in 24-tone equal temperament, building on Chalmers' work on tritriadic methods of building scales. The third, "Adjacencies," uses the tones of 11-, 13-, and 17-tone equal temperament which are closer than 17 cents. Surprisingly, these tones form a variety of dissonant "triad-like" chords.

Over the course of the set, a progression occurs from pieces based on triads and other tonal chords, to pieces based on clusters of adjacent harmonics. The "tonal" natures of the first two pieces are supplanted by the "cluster" nature of the last two, with "Adjacencies" being the pivot, being both "triad-like" and dissonant. Both equal tempered scales and just intonation are used in the pieces. In this paper, the focus will be on the harmonic structure of the first three pieces, although aspects of the final two pieces will also be mentioned.

INTRODUCTION

"Harmonic Colour Fields" (1996-1997) is a set of five computer pieces which explore static microtonal harmonic fields using a variety of algorithmic and permutational pitch and rhythm selection methods. The pieces are descended from the 1970s "drone" pieces of such composers as La Monte Young, Charlemagne Palestine, Hal Budd and myself, but they make greater use of slow harmonic progressions to make more varied musical surfaces. I wanted to make pieces where the quality of the harmony was the primary focus, and so used very simple rhythmic systems, plain electronic timbres, and a minimum of melodic structuring. In fact, in these pieces, any sense of melody is simply the result of how the harmonic material is articulated. That is, change in harmony, and not construction of melody, was my aim in making the pieces. Melodic qualities are a byproduct of this. The title refers to the "Colour Field" minimalist painters of the 60s and 70s.

I thought of these pieces an analogous to those paintings, in that they explored the varieties and shades of one particular harmonic musical colour.

PART ONE

The first piece, "Portrait of Erv Wilson," was started when I received a letter from Erv Wilson, surely one of the most significant music theorists active today, in which he pointed out that the tones of the Lambdoma were identical with those of the Farey Series, an arithmetical way of ordering a set of ratios. Further, that both of these structures had great similarity to the tonality diamonds of Harry Partch and Augusto Novaro. (Wilson, 1996) In "A Brief History of the Lambdoma," (Hero, 1995) Barbara Hero describes the history of the Lambdoma, a pre-Pythagorean multiplication and division table used an an anagram of ratios and musical harmonics. In the second century Nichomachus, among others, described it - an ordering of ratios of integers both above and below 1.

BASIC LAMBDOMA:

$$\frac{1}{1}$$

$$\frac{1}{2} \qquad \frac{2}{1}$$

$$\frac{1}{3} \qquad\qquad \frac{3}{1}$$

$$\frac{1}{4} \qquad\qquad\qquad \frac{4}{1}$$

If these ratios are treated as musical ratios, it is obvious that the ratios on the right leg of the diagram can represent harmonic ratios, and those on the left side of the diagram can represent subharmonic ratios. Further, rotating the diagram 45 degrees for ease of typing, and filling in the gaps to complete the matrix, reveals that the basic ratio pattern exists in each horizontal and vertical axis of the matrix:

1/1	2/1	3/1	4/1
1/2	2/2	3/2	4/2
1/3	2/3	3/3	4/3
1/4	2/4	3/4	4/4

Further, as Wilson points out, this contains all the ratios of the Farey series of order 4. A Farey series of order n is the ascending series of irreducible fractions between 0 and 1 whose denominators do not exceed n; the numbers 0 and 1 are included in the forms 0/1 and 1/1. For example, the Farey series order 4 is:

$$\frac{0}{1} \quad \frac{1}{4} \quad \frac{1}{3} \quad \frac{1}{2} \quad \frac{2}{3} \quad \frac{3}{4} \quad \frac{1}{1}$$

For musical purposes, Wilson proposes that the Farey series be carried out to the full 0/1 to 1/0 condition. This results in a symmetrical series around 1/1. It will also be noted that the intervals between each of the ratios of the Farey series is superparticular. Many tuning theorists, from ancient times to the present, regard superparticular ratios as the "fundamental particles" of tuning theory. Further, all Farey series, no matter how large, are similarly made up of a series of superparticular ratios. Here is the fully exanded Farey series order 4, with intervals between each of the ratios also shown.

Farey series: $\frac{0}{1}$ $\frac{1}{4}$ $\frac{1}{3}$ $\frac{1}{2}$ $\frac{2}{3}$ $\frac{3}{4}$ $\frac{1}{1}$ $\frac{4}{3}$ $\frac{3}{2}$ $\frac{2}{1}$ $\frac{3}{1}$ $\frac{4}{1}$ $\frac{1}{0}$

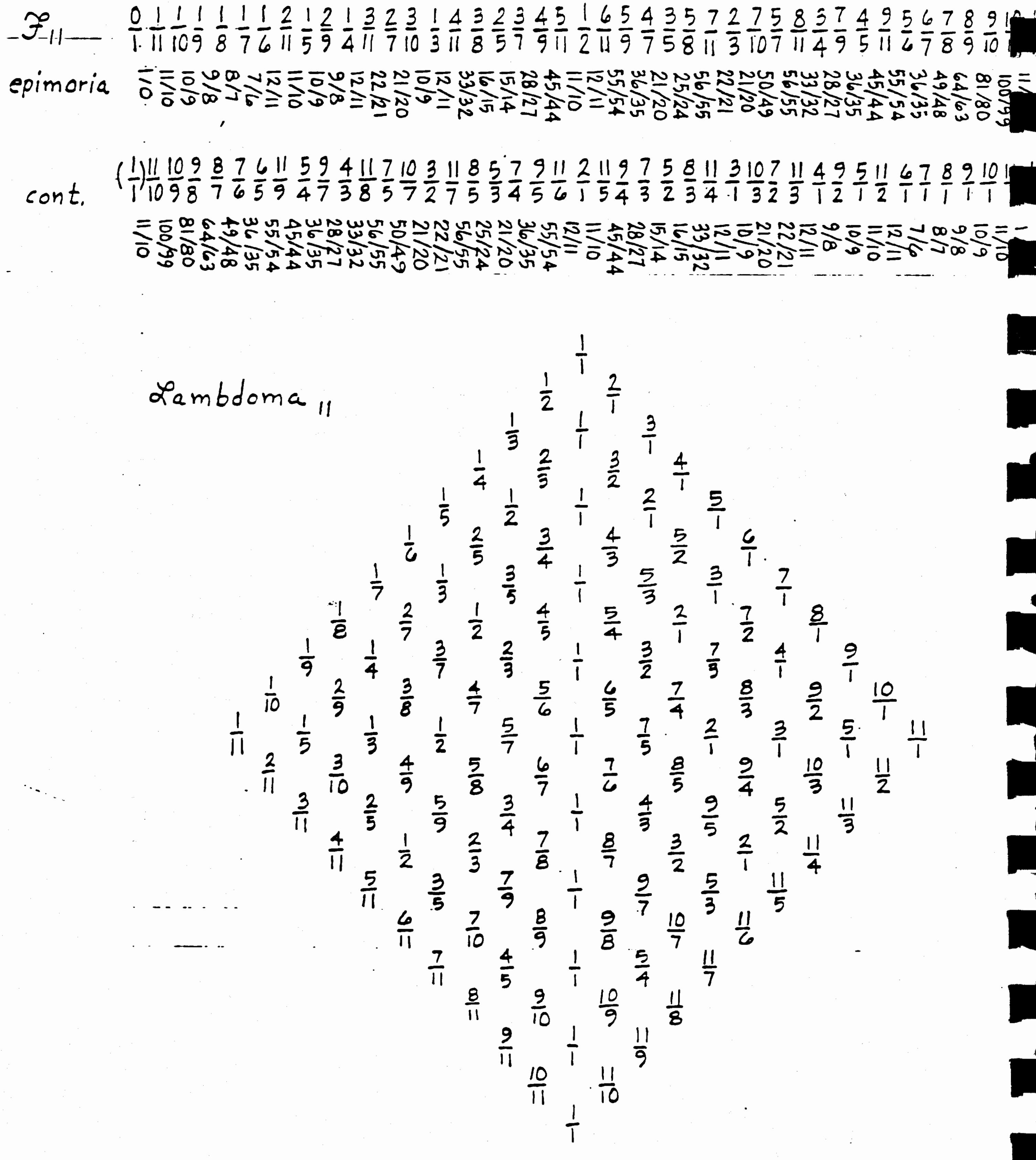
Intervals: $\frac{1}{0}$ $\frac{4}{3}$ $\frac{3}{2}$ $\frac{4}{3}$ $\frac{9}{8}$ $\frac{4}{3}$ $\frac{4}{3}$ $\frac{9}{8}$ $\frac{4}{3}$ $\frac{3}{2}$ $\frac{4}{3}$ $\frac{1}{0}$

In this realization, both the Farey series and the Lambdoma result in a matrix of octaves, fifths and fourths, with transpositions at all the available pitch levels. A similar, but more interesting structure results when a larger Farey series or Lambdoma is used. For example, the Lambdoma 11 results in a matrix of a series of harmonics 1 through 11 and subharmonics 1 through 11, such that a series of harmonics 1 through 11 is available on each of 11 fundamentals (subharmonics 1-11) and a series of subharmonics 1-11 is also available on each of 11 fundamentals (harmonics 1-11). On the next page, I reproduce Erv Wilson's diagram outlining the relationship between the Farey series order 11, and the Lambdoma 11. It will be seen that there are no ratios with prime number factors larger than 11 in this matrix. Hence, these ratios are in what is termed an 11-limit just intonation.

Further, when octaves are eliminated from these ratios, the result is a scale of 29 tones, which is identical to the 29-tone 11-limit scale Harry Partch was working with in the late 1920s, before he developed his full 43-tone scale. Here is the resulting 29-tone scale, which also contains all the ratios contained in Partch's "tonality diamond," a 6 x 6 matrix of chords built on harmonics and subharmonics 1, 5, 3, 7, 9, and 11. (Partch, 1974)

RATIO	CENTS	RATIO	CENTS
2/1	1200	7/5	582.5
11/6	1049.4	11/8	551.3
20/11	1035.0	4/3	498
9/5	1017.6	9/7	435.1
16/9	996.1	14/11	417.5
7/4	968.8	5/4	386.3
12/7	933.1	11/9	347.4
5/3	884.4	6/5	315.6
18/11	852.6	7/6	266.9
8/5	813.7	8/7	231.2
11/7	782.5	9/8	203.9
14/9	764.9	10/9	182.4
3/2	702	11/10	165.0
16/11	648.7	12/11	150.6
10/7	617.5	1/1	0

ERV WILSON'S DIAGRAM OF FAREY SERIES ORDER 11 and LAMBDOMA 11



I became fascinated with the listing of the intervals of the Farey series order 11, and decided to program them as a keyboard of pitches. That is, I wasn't concerned with having all 29 available pitches available in all octaves, but just with working with the particular order of ratios given in the Farey series. It results in an almost 7 octave keyboard with some interesting properties. Obviously 0/1 and 1/0 cannot exist as tones, so starting in the lowest octave we simply have subharmonics 11 to 9. The second lowest (and first full) octave has 6 tones from the 8th subharmonic to the 4th. The third octave has 11 tones from the 4th subharmonic to the 2nd. The fourth lowest has 21 tones from the 2nd subharmonic and the first. The upper octaves then invert this order. This means that within this scale, each axis of 11 harmonics or subharmonics is available, but only on the pitch levels it would exist at if represented by the tones of the Lambdoma. That is, the series of subharmonics 1/1 => 1/11 only exists using the fundamentals 1/1; 2/1; 3/1; 4/1; etc. available on this keyboard. This seemed to me to be a sufficiently interesting structure to base a piece on. However, since my main interest is in algorithmic composing, and not performing, I decided to not make the keyboard physical, but conceptual (that is, I didn't program a sampler to have this tuning, though I did do that with the Farey series order 9). And since the Lambdoma exists as a matrix, which is an easy form for computer sequencer memories to use, my "keyboard" became an 11 by 11 matrix of data inside the memory of John Dunn's "Kinetic Music Machine" algorithmic composing software. Each cell of this matrix consisted of a midi pitch number and a midi channel number. I was using a Roland Sound Canvas synthesizer, and its microtonal implementation allows only 12 microtonal pitches per midi channel, but with 16 available channels, (giving a possible total of 196 pitches) this has so far not proven to be a limitation.

I decided on a structure where a particular harmonic series and a particular subharmonic series would be combined to form the pitch materials available for one 45 second section. Eleven of these sections would consist of a linear descent from 11 to 1. The content of the ten intervening sections would be chosen randomly, and could include two harmonic, or two subharmonic scales in place of one of each. Additionally, the pitches of each section would also be chosen with a random algorithm, so that I would have control over the harmonic progression of the piece, but not its moment to moment details. Simple sawtooth wave timbres were used, which when combined with the tonal characteristics of the scales, gave the piece a brassy, almost majestic, fanfare-like character. This, I could live with. Here is the order of the scales used in the piece. "11H" refers to a scale of 1/1 2/1 3/1 etc. beginning on 1/11. "11S" likewise, refers to a scale of 1/1 1/2 1/3 etc. beginning on 11/1. Sets of scales in parentheses are ones that were chosen with a random algorithm.

SECTION	SCALES	
1	11H	11S
2	(8S	7H)
3	10H	10S
4	(3H	10S)
5	9H	9S
6	(8S	2S)
7	8H	8S
8	(1H	6H)
9	7H	7S
10	(6H	5S)
11	6H	6S
12	(5H	2S)
13	5H	5S
14	(7H	10H)
15	4H	4S
16	(10S	11S)
17	3H	3S
18	(2S	6S)
19	2H	2S
20	(6H	6S)
21	1H	1S

PART TWO

John Chalmers is best known for his magisterial "Divisions of the Tetrachord" (Chalmers, 1993) in which he describes just about every possible division of a tetrachord and the scales resulting from these. Less well known is his work on tritriadic scale formation. (Chalmers, 1986, 1987) Simply put, a tritriadic scale is a scale made up of three contiguous triads. Our major scale is one of these:

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TRIADS:         F   A   C
                        C   E   G
                                G   B   D

RESULTING SCALE: C   D   E   F   G   A   B   C
```

I wondered what sort of tritriadic scales could exist in differing equal tempered scales. My definition of a triad was two "thirds" piled on top of each other to make a chord of three notes. I took my cue from Brian McLaren, who had speculated that any interval between about 240 cents and 460 cents, could, depending on context, be heard as a kind of "third." (McLaren, 1995) In 24-tone equal temperament, this would mean that intervals of 5 (250 cents), 6 (300 cents), 7 (350 cents), 8 (400 cents), and 9 (450 cents) steps could all be heard as "thirds." There are 25 different combinations of these intervals. (For the mathematically completist, a combination of say, 6 steps and 5 steps may be thought of identical with a combination of 5 steps and 6 steps. However, acoustically, a chord with the interval of 300 cents on the bottom and 250 cents on the top sounds very different than a chord with 250 cents on the bottom and 300 cents on the top.) Some of these, such as a triad of 8 steps and 6 steps (400 cents and 300 cents) are familiar - it's the major triad of 12 tone tuning. Others, such as a triad of 9 steps and 8 steps (450 cents and 400 cents) are not - it's a kind of super-augmented triad. Out of each of these 25 triads, I made a tritriadic scale, which was a subset of 24 tone tuning. Here are a few of the resulting scales.

```
TRIAD 5-6 SCALE OF THREE: NOTES: 0 5 11 16 22 3(27) 9(33)
                      INTERVALS:  5 6  5  6  5       6
          RESULTING SCALE:NOTES: 0 3 5 9 11 16 22 0
                       INTERVALS: 3 2 4 2  5  6  2

TRIAD 6-7 SCALE OF THREE: NOTES: 0 6 13 19 2(26) 8(32) 15(39)
                      INTERVALS:  6 7  6  7      6      7
          RESULTING SCALE:NOTES: 0 2 6 8 13 15 19 0
                      INTERVALS:  2 4 2 5  2  4  5

TRIAD 9-8 SCALE OF THREE: NOTES: 0 9 17 2 10 19 3
                      INTERVALS:  9 8  9 8  9  8
          RESULTING SCALE:NOTES: 0 2 3 9 10 17 19 0
                      INTERVALS:  2 1 6 1  7  2  5
```

Clearly, with 25 different scales available, this method can provide a host of resources, even for a scale like 24, which has long had a reputation for being relatively resource-poor. In composing the piece I decided to use each of these 25 scales in one section. To keep things simple, and in line with Hopkins' theorem ("the blues = the truth"), I decided that each section would simply consist of a progression of the second triad followed by the first triad followed by the third triad. Using our major scale, this is the equivalent of a simple I-IV-V progression, except in this case both the I and the IV chord would sustain to the end of the section, so the final sonority in each section would be all the tones of the scale sounding together. Again, simple sawtooth waves were used for the timbre, and the rhythm was kept simple and chorale-like. Here is the order of the triads used to make the sections of the piece. You'll see that the triads tend to get larger as the piece progresses.

ORDER OF TRIADS WHICH FORM SECTIONS IN CHALMERS PORTRAIT:

SECT:	1	2	3	4	5	6	7	8	9	10	11
TRIAD:	5-5	5-6	6-5	5-7	7-5	6-6	5-8	8-5	6-7	7-6	5-9

SECT:	12	13	14	15	16	17	18	19	20	21	22
TRIAD:	9-5	7-7	6-8	8-6	6-9	9-6	7-8	8-7	7-9	9-7	8-8

SECT:	23	24	25
TRIAD:	8-9	9-8	9-9

PART THREE

"Adjacencies (A Drone on Breaking My Kneecap)" was composed in the Andreas Hospital in Amsterdam, after I fell and broke my kneecap. The week before, while composer-in-residence at the Dutch computer music studio STEIM, I had written a piece, "11/13 on 13/11", which explored the simultaneous use of 11- and 13-tone equal temperaments. I had noticed that some of the tones in the two scales were very close together, and as a means of counteracting boredom in hospital, began to speculate if this was the case with other scales. I compared 11, 13, and 17 tone equal temperament, and noticed the following correspondences. In the following chart all the pitches of 13, 17 and 11 tone equal temperament are listed, with the pitches of 13 and 11 lined up to their closest equivalent in 17. Equals signs show tones with less than 17 cents difference between them. Equals signs in parentheses were relationships not used in this piece. Single dotted lines connect tones in 13 tone and 11 tone.

```
13 TONE     17 TONE     11 TONE (cents)
0           0           0
92.307-----70.588-----109.090
            141.176
184.614     211.764====218.182
276.921====282.352
369.228(==)352.940      327.273
461.535     423.528====436.364
            494.116
553.842====564.704----545.455
646.149====635.292----654.546
738.456     705.880
            776.468====763.637
830.763(==)847.056
923.070====917.644      872.728
            988.232====981.819
1015.377    1058.820
1107.684---1129.408---1090.910
1200        1200        1200
```

From this set of relationships, three eight-tone chords were constructed for each of the three pairs of scales. These chords each sound like a four note chord with each of the notes beating, because of the closeness of the adjacent tones. The most interesting aspect of these chords is that they are symmetrical, with the differences between symmetrical pairs of tones being almost identical. As well, the three intervals between the median value of the tones are also symmetrical. Here are the chords used in each section of the piece. In this piece, each section slowly crossfades into the next. All values in this chart are in cents.

```
SECTION 1: 13 TONE - 17 TONE  DIFFERENCE   MEDIAN INTERVAL
           276.921   282.352   5.431
                                             279.908
           553.842   564.704   10.862
                                             81.445
           646.149   635.292   10.857
                                             280.635
           923.070   917.644   5.426
```

SECTION 2:	17 TONE -	11 TONE	DIFFERENCE	MEDIAN INTERVAL
	211.764	218.182	6.418	
				214.946
	423.528	436.364	12.836	
				340.106
	776.468	763.636	12.832	
				214.974
	988.232	981.819	6.413	

SECTION 3:	13 TONE -	11 TONE	DIFFERENCE	MEDIAN INTERVAL
	92.307	109.090	16.783	
				448.95
	553.842	545.455	8.387	
				100.699
	646.149	654.546	8.397	
				448.949
	1107.684	1090.910	16.774	

So for each section, the total chord is a symmetrical chord with the outer and inner tones also having symmetrical differences in cents. Further, the first and third chords have two symmetrical "third" intervals surrounding a kind of "second" interval, while the second chord inverts this, having a "third" sandwiched between two "seconds." The first section's chord, in fact, can be heard as a kind of "major/minor chord." If not triadic, at least the predominance of "thirds" of various sorts that occurs in the first two pieces is maintained here. Further, the appearance of dissonant "secundal" intervals in this piece sets the stage for the totally dissonant structures of the next two pieces. The timbre used is again, pure sawtooth, and the rhythm again, is slow, and permutational, aiming to allow a slow sense of changing observation of the different facets of the chords. (Actually, the appearance of all these symmetries in these chords makes me wonder about the quality of the morphine I was receiving in hospital while I was working on this piece!)

PARTS FOUR AND FIVE

Although the focus of this paper is on the harmonic structures used in the first three pieces, I should briefly deal with the harmonic aspects of the final two pieces. In "11:21:23 (A Drone for Mom and Felix's Birthdays)" (a reference to the fact that my mother and Felix Werder have birthdays only one day apart), chords of harmonics and subharmonics 11, 21, and 23 are used. The harmonic resources of the piece consist of six chords, three each of harmonic and subharmonic relationships. Further, the fundamentals of these chords are also related, either harmonically or subharmonically by the ratios of 11:21:23. This is an extension into higher harmonics of the use of adjacent harmonics used in the first piece (harmonics 1-11 as opposed to 21-23), and the use of the same chord on different pitch levels is an extension of the tritriadic technique of the second piece. Rhythmically, the same ratios are used in a variety of ways. The timbre this time is pure sinewave. This allows the wide "seventh" type spacings of the chord to "hang" in space more clearly than sawtooth waveforms would.

The final piece, "48=>53; 53=>48 (Midrashic Exegesis)" takes this technique even further. Here a chord of harmonics 48 through 53, spaced so that there is slightly more than an octave between each element of the chord, and a chord of subharmonics 48 through 53, similarly spaced, and with the top and bottom members of each chord being identical, are juxtaposed. (The octave spacing was necessary because a chord of such closely placed pitches, if placed all within a single octave, would simply fuse into what is heard as a single composite beating tone. It's true! Try it and see for yourself!) Each note progresses at its own rate, and the rates of each tone are in proportion to each other 48:49:50:51:52:53. This allows the twelve notes of the composite chord to slowly combine in different combinations, much like an English change ringing scheme. The timbre used in this piece was a square wave, accentuating the dissonant nature of the harmonies. Thus the overall set of pieces begins at the lower end of the harmonic series, in a kind of extended tonality, and through a series of compositional detours, progresses upward through the series, to end in its moderately high regions, in a world of relatively acute dissonance. The progression from consonance to dissonance is thus, in this set of pieces, one way, and complete.

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SOUND EXAMPLES:

1: Harmonics 1-11; Subharmonics 1-11.
2: 11 Harmonic series 1-11 as found in Lambdoma 11; 11 Subharmonic series 1-11 as found in Lambdoma 11.
3: The 25 "triads" of 24 tone equal temperament.
4: One tritriadic scale in 24-tone et. Based on 5-6 triad.
5: "Adjacencies," the eight tone chord for each of the 3 sections.
6: Opening of "11:21:23" showing basic chord type for the piece.
7: Beginning of "48=>53; 53=>48". All twelve pitches present in chord.