



Handwritten text in a square frame:
Kayan Chishom
Love in Numbers

LOVE IN NUMBERS (The secret of the Sixths)

„If you want to understand the Universe, think in terms of energy, frequency and vibration.“ Nikola Tesla

This work is about the marriage of two universal creative principles expressed through sound: the harmonic series, and the growth series more commonly known as the Fibonacci series. Their point of intersection is a fascinating one, both mathematically and musically. The harmonic series is perhaps more familiar to lovers of music but the way in which the Fibonacci series interacts with the overtones reveals much more to the listener regarding the nature of self-similarity, organic growth, inter-dimensional relationship and micro-macrocosm similarity. The Fibonacci series gradually approaches the irrational number phi (1.618 ...), more commonly known as the Golden Section. Some musicians have attempted to use the Golden Section by dividing their works accordingly along the time axis; in this work this proportion is approached on the vertical harmonic axis, which occurs in realtime. In this short essay I will give an introduction to both series and describe how they came to meet in the work „Love in Numbers“ for saxophone ensemble.

The harmonic or overtone series contains the basic musical foundations and every sound we hear contains several overtones, higher tones which sound out softly and stand in perfect whole number relationships to the main tone. The 13th overtone is 13 times the frequency of the fundamental tone. The beginning of the series can be wonderfully heard through the human voice (for example on the track Fibonacci Raga) or with such instruments as natural horns or monochords. Beginning with an octave, the intervals in the harmonic series gradually become smaller and smaller, approaching, but never reaching, the zero point. It was noticed early in human history that the simplest whole number ratios produced the most pleasing sounds and all of these relationships are revealed

in the beginning of the overtone series. Dividing the string exactly in half gives us the octave, a division of $2/3$ gives us the 5th, a division of $3/4$ the 4th, $4/5$ the 3rd and so on. Though we have assigned numbers in the usual sense to the steps of the overtone ladder it is important to realize that we are listening through our ears to the qualitative element of number instead of the usual quantitative element. By this I mean when we hear a musical 5th, we are listening to the sound and the quality of the ratio 2 to 3. There is a profound distinction to make between these two ways of apprehending number:

Understanding the foundation of the harmonic series gives us all the information we need for ascending higher up the ladder where the intervals become smaller and smaller. By using half the string we have doubled the frequency to attain the octave, by dividing the string in 3 we have multiplied the frequency by 3. And so, we can describe this harmonic series in the following way:

1, $1/2$, $1/3$, $1/4$

1, 2, 3, 4

We see that the series expands and contracts evenly and at the same time with neighboring whole numbers.

The first 16 overtones contain all of the intervals that are used in most music and allow us to fully experience the sound of the number relationships. The further we move away from the basic integer ratios like $1/2$ and $2/3$, the more complex the sounds become. One of the beauties in the overtone row is that our ears are able to experience the quality of number relationships and proportion whether we are musicians or not.

Over the last few years I have been gradually ascending the harmonic ladder and had created pieces for saxophone ensemble, which went up to the 50th overtone and beyond. I was interested in the quality of the overtones and the relationship of the numbers when the intervals become smaller and smaller. Above the 16th overtone most instruments are unable to play the overtones effectively and so I had to find a different way to make them sound without the use of computers or synthesizers. I made this by assuming the low C on my alto saxophone was already the 8th overtone and from there I had almost 50 overtones within my normal two and a half octave range. These I could then play with alternate and microtonal fingerings, which I had already developed much earlier. This was explored in my work „Inside C“ (2010) for 8 alto saxophones. Of course our „playing“ of the overtones is different to a string player who can finger them with flageolets but we have discovered that it is just as effective in bringing them out.

(A short interlude concerning the accuracy of tuning on the saxophone: with practice and the help of tuners we can execute minute deviations of cents, required when tuning according to the overtones. As the harmonic series is a natural progression we can also quickly develop a feeling for proportion and „feeling right“ when we move higher up on the ladder. From the 16th overtone upwards we begin to experience clusters of sounds but even here, a certain harmony can be heard when the overtones are well tuned.)

In the summer of 2011 at my master class in Greece, „The G-string of Pythagoras“, I was experimenting together with my students with different combinations of overtones. I was interested to know how it would sound if we played only even numbered overtones, prime numbered overtones, odd numbered overtones, etc. It was here when I decided to try the number sequence known as Fibonacci that this work was born.

The number sequence 0, 1, 1, 2, 3, 5, 8, 13, 21... is named after the 13th century Italian mathematician Fibonacci although it is surely much older than that. As with the numbers in the overtone series, these numbers reveal a certain quality of growth, only here each number adds to the preceding one to produce the following. In this way it contains a very different form of growth than the overtone series, which extends and contracts with neighboring whole numbers. The Fibonacci series is found throughout nature and it has an incredible amount of applications, from cauliflowers to the forms of spiral galaxies. The higher we go in the series, the closer we approach what is known as the Golden Section, best described as self similarity. When the ratio of the smaller part to the larger part is the same as the larger part to the whole, we have the Golden Section - in our bodies this pertains almost exactly to the position of our navels. The golden section or phi is an irrational number meaning it can never be expressed with whole numbers but only as a ratio, and the higher we go up the Fibonacci series the closer we get to it.

2/3	1.5
3/5	1.666 ...
5/8	1.6
8/13	1.625 ...
13/21	1.615 ...
21/34	1.619 ...

Basically, the self-similarity in proportion provides the fundamental for reproduction. Proceeding in this way we can make the beautiful spiral form we know so well intuitively. (See my diligent sketches on the worksheet page)

What we perhaps do not know so well is the sound of such a principal. Having mentioned the ability we have to experience the sound of the musical ratios in the overtone row we are now well equipped to experience this spiral form approaching phi.

The first epiphany came when we applied the Fibonacci numbers to the overtone series, playing only overtone 1, 2, 3, 5, 8 and so on. The two series begin in unison but from the 3rd overtone they depart in the most amazing way. From that point on, the Fibonacci numbers produce what first sounded to me like a series of repeating 6ths, somewhere between major and minor sixths. I was astounded to discover that no matter how high we went in the row, the 6ths kept on repeating.

What struck me was the quality of these 6ths. At the same time they seemed like a cadence or a closing and also a kind of opening up to the next 6th, somewhat like buds within flowers opening out to the next row. Could this be the quality of self-similarity and organic growth expressed through sound? I was immediately interested to discover the quality of these intervals as the Fibonacci ladder spiraled upwards. If the row itself approached the Golden Section then how do these beautiful intervals behave the higher we go up the row?

(Another short interlude: for the 3 weeks following the Greece master class I was truly obsessed by the Fibonacci work and had ceaselessly been sketching out ideas for a musical version of it. Then one rainy September Saturday in Berlin I happened to look down on the table of a cafe and see a small postcard. On it was the title „Life in Numbers“ and the subtitle „200 youths from Neukölln and Rotterdam sing and dance the Fibonacci numbers“. I still haven't quite re-

covered from that shock. Well, on the postcard the first 32 Fibonacci numbers up to 2,178,309 were listed and so I decided to use these in my piece.)

During this time I was sketching Fibonacci spirals to internalize the growth series. It occurred to me that what I was drawing was but a two dimensional representation of the spiral. The growth spiral itself existed in 3 dimensions as we perceive it and even this form could be but an expression of an order from a higher dimension. I recalled a book of Rudolf Steiner I had read some time ago in which he unfolded the cube onto two-dimensional paper in order to explain and facilitate a dimensional shift in our understanding and then proceeded with a 4 dimensional figure called a tesseract which unfolded to the cube as we know it. I would not be surprised if such a potent and all-encompassing creative force like the Fibonacci growth spiral is an expression of a creative model from a higher order of spatial construct which requires a jump in our thinking to grasp, even if only in theory. Perhaps the sound work can bring us a step closer to understanding, in the way Mr Tesla explains in the quote above.

As I wrote before about the quality of numbers, I was now interested to explore the quality of the series through sound as we progress upwards. If the series approaches the irrational number phi then how do the intervals behave? The very first point of departure from the overtone row when the 3rd overtone leaps to the 5th is of course a major 6th, but from that point on the intervals are closer in feeling to an inverted major third. This is because their tuning gives us the feeling of cadence or arrival on the upper note. The 5th overtone resolves to the 8th and at the same time the 8th opens up and leads to the 13th. At this early point the 8th feels like the tonic but if we remove the fundamental from the sound each one of the new Fibonacci sixths feels like the tonic. It is here where the Fibonacci sequence touches the overtone series and reveals the two creative principals intermingling in sound.

Love in NUMBERS

worksheet

Handwritten musical notation on a staff with various annotations:

- Annotations: -60 , -30 , $\# +5$, $+38$, -29 , $+4$, -30
- Notes: $\#$, \flat , \natural
- Numbers: 6 , 41 , 13 , 7 , 29 , 21 , 8 , 26 , 34 , 9 , 29 , 55 , 10 , 33 , 89 , 25 , 144 , 12 , 33 , 233 , 15 , 377 , 14 , 27 , 10 , 101

Handwritten musical notation on a staff with various annotations:

- Annotations: $+3$, $+36$, -30 , -12.5 , $+35$, -31 , $+1.7$
- Notes: $\#$, \flat , \natural
- Numbers: 10 , 15 , 33 , 987 , 16 , 34 , 1597 , 17 , 28 , 2584 , 18 , 37 , 4181 , 19 , 34 , 6765 , 20 , 32 , $10,945$, 21 , 35

Handwritten musical notation on a staff with various annotations:

- Annotations: $\# +34$, $\flat -32$, $+1$, $+34$, -33 , $+1.02$, $+33$, -33
- Notes: $\#$, \flat , \natural
- Numbers: $17,710$, 22 , 34 , $28,655$, 23 , 33 , $46,365$, 24 , 35 , $75,025$, 25 , 33 , $121,393$, 26 , 33 , $196,418$, 27 , 33 , $317,811$, 28 , 34 , $514,229$, 29 , 33

Handwritten musical notation on a staff with various annotations:

- Annotations: -0.4 , $+32$, -34 , -7
- Notes: $\#$, \flat , \natural
- Numbers: $822,040$, 30 , 32 , $1,346,269$, 31 , 34 , $2,178,309$, 32 , 72

Grand fine

19.4454365hz

Handwritten musical notation on a staff:

- Annotations: \flat , \flat
- Notes: \flat , \flat
- Numbers: 2 , 3 , 5

Taking this into account I analyzed the first 32 Fibonacci numbers in their cent deviation from tempered tuning. My question was, which interval are we approaching as we move up the row? On my workbook sketch for the piece I have calculated the first 32 Fibonacci numbered overtones from a fundamental of 19.445 hertz. Naturally this note is lower than what I can play on my alto saxophone but it is nevertheless just within the perceivable range and was also the imaginary fundamental of my previous piece „Inside C“ as it made my low C on the alto saxophone the 8th overtone. The changing 6th (I hear it more as an inverted major third) as we climb the tonic spiral seems to be approaching the inverted major third 33 cents below the normal tempered major third. It is the quality of this interval, which we approach during the piece, that interests me.

Each time the overtones of the Fibonacci row have overshoot the top of the normal saxophone range I have transposed them back down into the range. By the 32nd Fibonacci number (Overtone 322,178,309) I am transposing 21 octaves down into my range. The numbers above the notes indicate cent deviation from tempered tuning and the numbers in circles indicate cent deviation from the respective inverted major thirds bridging the adjacent overtones.

Each relationship between adjacent overtones is a branch of the tree and cannot be treated as representing the Golden Section itself. With several branches sounding together and ascending up the spiral we can begin to develop a feeling for the ratio itself and the genesis of self-similarity. To outline the nature of the branches as we ascend, the piece „Love in Numbers“ basically freezes parts of the larger tree by holding chords. Each of the chords has a slightly different quality as they are from different levels of the spiral, albeit transposed back down into my saxophone range.

It is as if I would show someone who had never seen a tree before many snapshots of the details of the branches and parts of the tree because I didn't have

a lens big enough to capture the whole.

Does the spiral truly spin out into space without ever repeating a note? I had calculated the first 2000 Fibonacci numbers and checked their factors. None of the numbers are divisible by 5 meaning the 5th overtone (in my piece a 14 cent lowered E) does not reoccur. From this I can safely deduce that the spiral does indeed spread out into infinity without ever repeating a single note in any octave. I must admit I am still coming to terms with that concept.

Throughout the history of music in the last 3000 years we have been occupied with closing the circle - tempering the intervals such as the 13/8 golden section relationship so that our instruments would have it easier and we could find our tonic again at a higher octave. There is surely a direct relationship between the 12 signs of the zodiac, 12 months of the year, 12 disciples of Jesus, and 12 5ths in the circle of 5ths. What all of these have in common is their construction by man - the spiral form transcends Homo Sapien's tools and gives us more powerful tools. It could well be time to allow a never-repeating spiral form to break open the artificially constructed temple of the 12 - to break open the head and heart for good so to speak.

I mentioned in the introduction that this work lays out these particular proportions on the vertical harmonic axis rather than the time axis. I realize I am using a simplified model to explain this and yet I am at a loss as to how better I can lay it out. When it comes to attempting to divide music along the time axis to mirror these kinds of proportions the path is fraught with difficulties. Time is not a part of the three dimensions we perceive and it is a slippery customer to appropriate or to cut up subjectively. The way it will be received will be every bit as subjective as the memory of the cutter. Which moment am I in? This one? This one? At which moment was the Golden section? That one? That one? I believe the hyper-dimensional structures that find expression in our perceived three

dimensional spirals and helixes operate outside our linear perception of time. By this measure, the now in the perception in a single tone and in particular the highlighted Fibonacci tones in particular are able to transcend our still limited perception of time by giving us a widened comprehension of the structure in the single moment.

There are two important concepts taken from the world of Pythagoras relevant to these themes - Apeiron (Eternity) and Peras (Limit). Apeiron does not have the positive connotation of the modern usage of eternity but rather indicates more the chaotic state. It was the role of man to bridge these two opposites, or to bring Apeiron down to earth through the usage of Peras. In this way, the eternal length of the monochord with its limitless possibilities of division were „brought down“ to earth by the division in whole numbers to make harmony. In the same way this piece uses the saxophone to „bring down“ information from higher octaves into the audible range. The saxophone may not be as perfectly accurate as a sine wave generator but in the act of bringing Apeiron down through Peras and powered by the breath, it is infinitely more potent.

Having said that, ancient Greece was also an important transition in the history of music when sound began to be analyzed in such ways, using whole numbers to explain and illuminate harmony. At that time there were still remains of a more ancient culture in which sounds were regarded as the direct expression of the gods and were not analyzed as such. In Ancient Greece, places of oracle like Dodona and Trophonius used naturally occurring sounds like wind through the trees as an expression of guidance from above. In the right state of mind one could impart messages within the sounds. Gradually this form of intuiting sounds disappeared but it is certainly not lost for good. Like intuiting and enjoying the qualitative aspect of number through sound, we can sit in quietude next to a bubbling stream or a whispering tree and allow the voices within to speak to us. It will surely be different each time.

And I would hope that one could listen to „Love in Numbers“ with a similar ear-set. As much as possible I have taken the „player“ out of the equation. A breath passes through the copper of the saxophone, ignites an overtone through the reed and then vanishes into air again. I always like to think of the overtones being there all the time anyway - the breath and reed simply highlight them, this time via the Fibonacci spiral form.

The principles on the other pieces on this CD are different, with the player and his intention playing a more active role in the music making. On „Prelude to a Bliss“ I play the monochords and sruti boxes in my music room in Cologne. All of the instruments and the wood of the room itself are tuned to C. Track 4 is a kind of Fibonacci Raga (so much so, I even called it that) with the saxophone and sruti box in which the saxophone always returns to overtone 5, 8, 13 and 21 throughout the piece, interspersed with some overtone singing.

Finally, the third creative principle, and the one that in certainty rivals the force of the other two, is contained in the title of this work. Overused as a word, perhaps underused as a principal, it is the one of the three creative forces unique in its form to the resonant blue/green sphere this work springs from. Bless her soul.

Hayden Chisholm

Barcelona 2011



Pedja Avramovic and Hayden Chisholm sharing a joke during the recording session at Studio P4, Berlin.

THE WELL TEMPERED SRUTI BOX

My Sruti box is a small laptop-sized wooden drone instrument originating from India that has become very dear to me. Last year I discovered a way to play my saxophone and the Sruti box at the same time. Since then I have enjoyed their dialogue together.

This piece was born in Berlin at the wonderful P4 studios, the old

East Berlin radio studios. I had spent several days recording and my embouchure was completely through. Out of pure desperation I reached for the Sruti box and saxophone and began to improvise some simple lines over a simple drone. That was the beginning of a journey inside the keys.

Yes, this little wooden box is chromatic and well-tempered, meaning the 5ths that make up these drones are slightly off from the perfect overtone 5th - only with the Sruti box as opposed to the piano this provides some useful higher overtones which can be played with.

„Sruti“ are the small intervals in Indian music, the finer shades of tonal color which add depth to the Raga, which itself means „hue“, or “beauty“.

The word Sruti is thought to mean “that which is heard”, and even “truth”. By this token I sometimes call her my “listening box” or my little “truth” box.

The Western tradition prides itself on its flexibility of transposition through the means of well tempering- but gaining this meant losing the deeper core of individual keys. After all, how can I get to the soul of a key when not a single note I have, other than the octave, is in tune with the keys' natural overtones? In this sense this piece explores some of the terra incognita between the tempered and the natural harmonic landscape - the desert between the light, movable tonality of Rome, and the deeply rooted raga of Rajasthan.

I have often wondered if the different keys really do have different colors, as some claim. Because the individual pieces are so short in this work, one has a good chance to appreciate them as different colors, if one were so inclined to do so. I leave this question open for the listener to decide.

„The Well Tempered Sruti Box“ modulates through all 24 major and minor keys. In each of the keys the saxophone embarks on a short improvisation above the Sruti box. The exact scale was chosen on the spur of the moment but the 12 major and minor keys remain intact.

The entire work was recorded on June 16, 2011. For me this has always been a special day- Bloomsday- the day on which Leopold Bloom set out in Dublin after his pork kidney breakfast and changed the world and the word forever. This small work does not aim to change anything as large but it also works with hyper-perception of the ordinary and a retake on an ancient tale, in this case the tale of the tones. Amongst the rubble of the Western harmonic model, still surrounded by more than 4 and a half minutes of sculptured silence, it is like a little match box house that has been carefully rebuilt by a curious soul. Now I can sit back and observe it before the tramontana wind blows it away.

Hayden Chisholm