

The Harmonic Algorithm: Reflections

This document serves to reflect on the concept, process, degrees of success and discoveries made throughout the duration of developing, studying and creating the 'The Harmonic Algorithm' (hereby referred to as the 'method document').

This work was carried out over more than a year's duration. This period encompassed the genesis of the idea through the acquisition and customisation of an instrument to put it into practice, then into real life application of the concepts and techniques created throughout its development in a very much full time manner. By this completed stage of its development, these discoveries have been put into high levels of performance on multiple continents, set to record alongside professional performers of their own instruments (audio examples 67 & 68) and thoroughly explored in improvisatory settings. Thus, many theoretical areas of exploration have been discarded, other unexpected areas of discovery have been found through blind trial and error and the process of development has taken numerous unexpected turns that would not have occurred in a purely academic process of development. I believe that in this area of practise led research, this duality (although substantially lengthening the duration) has enriched and guided the content of the academic work in a manner that grounds and validates its content into a real world context.

When considering what to study for this major and open ended work, I had three objectives:

1. The primary practical focus of the project should be practising, not performing.
2. The work should create genuinely new developments for my own playing and for its field of study in general.
3. The work should build logically on the previous content of my master's degree.

The reason for the first point was that over recent years I have had an abundance of performance opportunities and the two major assessments previously during my studies had also been performances. Performance assessments are a great motivator for overcoming technical or stylistic shortcomings, but place emphasis on presentation over attention to detail. I was at a point that I was generally happy with my playing and wanted to apply myself to my practical studies in a way that would bring about a fundamental paradigm shift in my musicianship, exploring a specific and carefully chosen area of study in a thorough and methodical nature that I don't believe a performance assessment would provide.

The area of study that I chose (relating to point 2) was natural harmonics; I had previously utilised artificial harmonics extensively but had never committed myself to the study of natural harmonics, making it was a logical area of weakness to develop. Having worked previously with overtone instruments, understanding the physical principles behind overtones in some detail, it gave further motivation for study in this area. I also feel that there is a limited amount of resources available to players interested in learning about this area and that apart from a few notable exceptions such as Michael Manring's use of highly modified instruments or Steve Bailey's artificial harmonics technique, that there haven't been very many truly innovative developments to the field beyond Jaco Pastorius brought to the instrument. I decided that rather than try and create a 'paradigm shifting' development in instrumental virtuosity, that I would create a working methodology for utilising this technique which could be applied by myself and other players, perhaps having the longer term effect of opening up the field of study to further developments.

The third point was very simple to fulfil. Throughout my previous performance assessments, I had begun to introduce an instrument which I've referred to as an 'Electric Contrabass Cittern': a five string bass with a redesigned 'standard' tuning, intended for an extended technical range in performance (discussed in depth in the method document). In Performance One I performed a couple of showcase compositions with it (versions of these are presented in audio examples 67 & 68) and in Performance Two I partly dedicated my studies to integrating its extended performance capabilities usefully into an ensemble context. I found that this instrument was very well suited to performance with natural harmonics, so my objectives for this project neatly connected with my previous development, allowing me to expand my performative repertoire in a logical direction. The use of changing tunings dynamically was introduced while the concept was being developed in order to further extend the scope of possibilities, taking inspiration from Michael Manning's work with artificial harmonics. In the realm of this study, I have been primarily interested in applying the performance developments to my 'Electric Contrabass Cittern' instrument. However, the work should be equally applicable to a standardly tuned instrument. For the purposes of making the document useful to a much wider audience as well as whatever 'scientific validity' it may provide, I also included charts and methodology for standard tuning.

A major component of the work, the depth of which could easily be overlooked, is the 'Harmonic Algorithm' data chart itself (located in Section Two). Much of the work's early development time was dedicated to the creation of this chart and it went through many different incarnations before completion. There was also a fourth chart completed which was omitted from the final work in the process of development. The initial concept for the project was developed whilst the instrument to perform it on was being acquired and modified; it took some time to get hold of the parts, so work at this time was theoretical. I had originally planned for the re-tuner to extend in a third position beyond C to D, to provide more upper range harmonic options, however when tested in reality it was not practical. Of the different options studied, I found a movement between B and C to be the most practically useful. The proposed composite harmonic series is shown below:

12 EAeGd

E1 A1 E2 E3/A2/e1 G1 E4 A3 e2 A4 G2/d1 e3 G3 e4 d2 G4 d3 d4

13 EAeGb ↔ C → d

E1 A1 E2 E3/A2/e1 G1 E4 A3 e2/b1 C1 A4 G2/d1 e3 b2 C2/G3 e4 d2 b3/G4 C3 d3 b4 C4 d4

An excerpt from a much earlier (unfinished) version the chart demonstrates a few important notes on it's development.

- The table originally only featured the top three lines, presenting each inversion of each three notes. This was expanded with chromatic bass notes, but the table's organisation and format soon became unwieldy under the mass of information that it presented.
- The order of the triads was taken directly from my notebook, simply 'as derived'.

E Ae Gb	B D F#	B F# G	B G D#	B D D#	B D E	E F# B
1	Bm	B ^{b13no3}	B ⁺	B ^{#9no5}	Bm ^{sus4no5}	E ^{sus2}
2	D6 ^{no5}	F# ^{sus4b9no5}	G ⁺	D6 ^{b9no5}	D6 ^{sus2no5}	F# ^{b7sus4}
3	F# ^{sus4#5}	G ^{Δno5}	D# ⁺	D# ^{Δ#5}	E ^{b7no3}	B ^{sus4}
B	Bm	B ^{b13no3}	B ⁺	B ^{#9no5}	Bm ^{sus4no5}	B ^{sus4}
A#	A# ^{b9#5}	A#6 ^{b9#5}	A#6 ^{b9sus4no5}	A# ^{b9add11no5}	A# ^{b9b5}	A# ^{b9b5#5no3}
A	A6 ^{sus2/4no5}	A6 ^{7sus2no5}	A ^{7sus2b5}	A ^{sus2/4b5}	A ^{sus2/4}	A6 ^{sus2}
G#	G#m ^{7b5}	G# ^{- Δb9}	G# ^{- Δ}	G#m ^{#11}	G#m ^{#5b5}	G# ^{#5}
G	G ^Δ	G ^{Δno5}	G ⁺	G ^{addb13}	G6	G6 ^{Δno5}
F#	F# ^{sus4#5}	F# ^{sus4b9no5}	F#6 ^{sus4b9no5}	F#6 ^{sus4#5}	F# ^{7sus4#5}	F# ^{b7sus4no5}
F	F6 ^{b9b5}	F ^{b9bb3b5}	F ^{7sus2b5}	F6 ^{7b5no3}	F6 ^{Δb5no3}	F ^{Δb9b5no3}
E	E ^{7sus2}	Em ⁹	E ^{- Δ}	E ^{Δ#6no3}	E ^{- no3}	E ^{sus2}
D#	D# ^{Δ#5}	D# ^{#9#5}	D# ⁺	D# ^{Δ#5no3}	D# ^{Δb9#5no3}	D#m ^{b9#5}
D	D6 ^{no5}	D6 ^{add11no5}	D6 ^{sus4b9no5}	D6 ^{b9no5}	D6 ^{sus2no5}	D6 ^{add9no5}
C#	C# ^{7sus4b9no5}	C# ^{7b5sus4}	C# ^{7sus2b5}	C# ^{7b9bb3}	C#m ^{7b9no5}	C#m ^{7sus4}
C	C ^{Δsus2#11no5}	C ^{Δ#11}	C ^{- Δ}	C ^{- Δ9no5}	C ^{Δ9no5}	C ^{Δb5}

In this excerpt from the next iteration of the chart, you can see that the order of triads has been resolved (presented in ascending intervals) and the data is presented much more logically by 'flipping the axis'. A system to show the location of overtones was also included.

E Ae Gb	E	G	G#	E ^{#9no5}	G6 ^{b9no5}	G# ^{Δ#5no3}	A2/e1	G1+3	E4/e4
	E	G	A	Em ^{add11no5}	G6 ^{sus2no5}	A ^{- no3}	E3/e1	G1+3	A3
	E	G	B	Em	G6 ^{no5}	B ^{sus4#5}	E3/A2/e1	G1+3	e2/G4/b1+3
	E	G	C#	Em6 ^{no5}	G6 ^{b5no3}	C# ^o	E3/e1	G1+3	A4
	E	G	F#	Em ^{add9no5}	G6 ^{Δno3/5}	F# ^{b7b9no3/5}	E3/A2/e1	G1+3	b2
	E	G	D#	E ^o	G6 ^{#5no3}	D# ^{b9no5}	E3/A2/e1	G1+3	b4
	E	G#	A	E ^{add11no5}	G# ^{b9#5no3}	A ^{Δno3}	E3/e1	E4/e4	A3
	E	G#	B	E	G#m ^{#5}	B6 ^{sus4no5}	E3/A2/e1	E4/e4	e2/G4/b1+3
	E	G#	C#	E6 ^{no5}	G# ^{sus4#5}	C#m	E3/e1	E4/e4	A4
	E	G#	D	E ^{7no5}	G# ^{b5#5no3}	D ^{sus2b5}	E3/A2/e1	E4/e4	G2
	E	G#	F#	E ^{add9no5}	G# ^{7#5no3}	F# ^{b7sus2no5}	E3/A2/e1	E4/e4	b2
	E	G#	D#	E ^{b5}	G# ^{b13no3}	D# ^{sus4b9no5}	E3/A2/e1	E4/e4	b4
	E	A	B	E ^{sus4}	A ^{sus2}	B ^{7sus4no5}	E3/e1	A3	e2/G4/b1+3
	E	A	D	E ^{b7sus4no5}	A ^{sus4}	D ^{sus2}	E3/e1	A3	G2

Finally, this second sheet was expanded into the finished version by widening the central area to include chromatic bass tones.

The final section of the project represented its development into a practical methodology for study. One of the greatest challenges was how to incorporate practising itself into the format of the work. The way I intend to do this with regard to this document is to provide reflections on the process of practising the exercises provided with the method document as audio examples.

The first discovery when beginning practising the Melodic Development exercises was that there are usable nodes for Overtone 4 in the few centimetres above the 24th fret. There is also a usable node in that area for 'Overtone 5'. On the G string this is a D in pitch and is very useful for higher melodic playing. I would not consider it usable as a tapped harmonic and although it exists in more locations on the neck, as I only commonly use noded harmonics in the upper area of the fingerboard, it is more suited to treatment as a 'substitute' for an artificial harmonic and not for insertion into The Harmonic Algorithm. These additional higher nodes allow for a great deal of melodic freedom in the higher registers, inside a physically small area of the instrument.

I also quickly established a repertoire of artificial harmonics. I have previously studied artificial harmonic technique a great deal, but when combining with natural harmonics I found it preferable to have an established 'toolbox' to use, rather than just choosing them ad hoc. The ones I used in the Melodic Development chapter are listed in the chart below:

String	Fret	Node	Overtone	Pitch
G	12*	19 or beyond 24	2	D
G	7	12	3	D
G	6 or 11	11, 18 or beyond 24**	3 or 2	C#
e	9	14 or beyond 24	3	C#
e	5 or 10	Beyond 24 or 17***	3	A
e	10	17	2	A
G	3 or 10	22	3 or 1	F
e	2	14	1	F#
e	1	13	1	F
A	5	17	1	D
A	4	16	1	C#
A	3	15	1	C
E	3	15	1	G
E	2	14	1	F#
E	1	13	1	F

*Can be without node, only beyond 24.

**Only for fret 6. Fret 6 and 11 are connected with nodes 11 and 18, respectively.

***Only for fret 10.

Initially, I found the re-tuner lever much more effective for melodic playing than for harmonic. However, with more time invested in practising I found that it became incredibly effective for harmonic movements. There is a technical roadblock in that it is very hard to play a new bass tone at the same time as operating the lever. The problem demanded creation of a new technique in my repertoire, in which I 'pass' the role of fretting the bass part from my left hand to right. An articulation is achieved on 'the pass' by tapping the next note with forefinger, it is then possible to articulate the string by using the thumb. I found that with practise, because of the articulation achieved on 'the pass', it became possible to very quickly switch hands back then forth in order to activate subsequent

overtones. The musical effect of changing the bass note as the higher overtone enters the harmony through portamento is incredibly effective and immediately pleasing.

Because it is usually impossible due to technical limitations to play an entire voicing on the downbeat, effective use of tensions and suspensions is very important. I found that the harmonic exercises chosen in the method document were very effective in facilitating this and throughout my practising I made a conscious effort to experiment with different styles of arpeggiation, in order to build the biggest and most fluent practical vocabulary. By the later stages, it felt very fluent and natural to move through harmonies in this way.

I found that the two practical chapters (on Melodic and Harmonic Development respectively) complemented each other very well, and in a much more beneficial way than I had foreseen. They not only both provide unique and differing insight into the musical application of this technical area but both force mastery of different applications of the technique to musicality. I found the fluidity and musicality of my playing to have made noticeable leaps when moving back and forward between blocks of practising the melodic and harmonic repertoire separately. I also found that while the top range of the Composite Overtone Series (above b3) was not very musically pleasing in harmonic applications (generally too piercing and thin sounding to blend effectively) that it was incredibly effective in melodic application. Because this register was left largely unused when moving through harmonies, I found it much easier than expected to combine melodic and harmonic techniques in order to imply melodic lines and motivic developments throughout a chord progression.

A practical shortcoming of the studies' analytical nature is that because the spreadsheet requires voicings of exactly three notes, there are occasionally harmonic possibilities missing from the results. For example, it may be possible to play a pure triad with just the bass tone and two overtones, however all possibilities for a third overtone could be tensions resulting in only extended voicings being listed. Fortunately, once an awareness of this and a little familiarity with interpreting the results is achieved, it is very easy to discern what possibilities may exist through omission of a higher tension.

The biggest gain I attained from the practical development sections was a deep and functional knowledge of my instrument's possibilities in this area of technique. After the numbers are crunched, possibilities discerned and a few dozen hours spent mastering them in practice, The Harmonic Algorithm serves primarily as a creative tool, providing insight, illuminating hidden possibilities and provoking experimentation.

While this study has completed what it set out in its objectives, the greater work does not propose to be complete. It is the nature of the practising process that you can never bring the task to a point of completion, but merely to make ongoing progress in a practical manner over targeted areas of functional usefulness. A logical direction for expansion on these fundamental concepts is through exercises focussing on musical application of these techniques. In fact, an exercise for this purpose was created using the traditional melody 'The Parting Glass'. I didn't include this in the scope of the present study due to time and word constraints, however the logical progression would be to develop the fundamental concepts using musical exercises such as these. The score for these exercises is given below:

The Parting Glass

D (Bm Aolian)

Freely & Expressively

Four staves of music in 4/4 time, key of D major (Bm Aolian). The score includes various musical notations such as eighth notes, quarter notes, and half notes, along with dynamic markings like *ff* and *fz*. Chord symbols are placed above the notes, and fingering numbers (1-5) are indicated below the notes. The piece concludes with a double bar line.

Chord symbols: Bm, A, Bm, F#m, Bm, G, D, Bm, D, Em, Bm, A, D, G, D, Bm.

Fingering numbers: b2, e3, G2, e2/b1, A3, G2, e3, b2, e3, G2, b2, A3, e3, G2, e2/b1, A3, G2, e3, b2, b3/G4, A.H., e3, G2, e2/b1, b2, A.H., b2, A.H., b3/G4, A.H., b2, A.H., b2, A.H., b3/G4, A.H., b2, C2/G3, b2, e3, G2, b2, A3, e3, G2, e2/b1, A3, G2, e3, b2, b3/G4, A.H., e3, G2, e2/b1, b2, e3.

The Parting Glass

G (Em Aolian)

Freely & Expressively

Four staves of music in 4/4 time, key of G major (Em Aolian). The score includes various musical notations such as eighth notes, quarter notes, and half notes, along with dynamic markings like *ff* and *fz*. Chord symbols are placed above the notes, and fingering numbers (1-5) are indicated below the notes. The piece concludes with a double bar line.

Chord symbols: Em, D, Em, Bm, Em, C, G, Em, G, C, Am, Em, D, Em, G, C, G, Em.

Fingering numbers: b3/G4, A.H., C2/G3, e3, G2, C2/G3, A.H., A.H., b3/G4, A.H., C2/G3, b3/G4, G2, A.H., C2/G3, e3, G2, C2/G3, A.H., b3/G4, C4, A.H., C2/G3, e3, b3/G4, C4, b3/G4, C4, C3, b3/G4, A.H., C2/G3, b3/G4, G2, A.H., C2/G3, e3, G2, C2/G3, A.H., b3/G4, C4, A.H., C2/G3, e3, b3/G4, A.H.

The Parting Glass

C (Am Aolian)

Freely & Expressively

The musical score for 'The Parting Glass' is written in bass clef, 4/4 time. It consists of four staves of music. Chords are indicated above the staff, and notes are labeled with letter names and octave numbers below the staff.

Staff 1: Am, G, Am, Em. Notes: e3, G2, C1, A3, G1, C1, G2, G2, e3, G2, C1, e3, G1, G2.

Staff 2: Am, G, Am, F, C, Am. Notes: C1, A3, G1, C1, G2, C1, G2, e3, A.H., C2/G3, G2, A3, e3.

Staff 3: C, F, Dm, Am, G. Notes: C2/G3, e3, A.H., C2/G3, e3, A.H., A.H., e3, G2, C1, e3, G1, G2.

Staff 4: Am, G, C, F, C, Am. Notes: C1, A3, G1, C1, G2, G2, e3, A.H., C2/G3, G2, C1, A3, e3, G2.

Another obvious area for expansion is to expand around the circle of fifths, simply repeating the process performed by this study and applying it new to musical examples. My next studies will be in F and A, progressing afterwards to Bb and E (etc.). The usefulness of the musical notation system 'created' in this study should also not be understated, as it 'grounds' and clarifies the technique a great deal, as well as providing a clear method for developing practise materials and compositions with this instrumental style specifically in mind.

Overall, I have found the tonal quality of overtones to be incredibly useful in bass playing due to the nature of how they 'enrich' bass tones rather than fill up the low end with unwanted frequencies. The progress made in this study has provided me with a concrete technical grasp and deep understanding of their nature and has been a valuable and practical expansion to my bass playing technique. This work represents the starting point and foundation for a much larger and ongoing direction for development.

Bibliography & References

Barrett, E., Bolt, B. (2007) *Practice as Research: Approaches to Creative Arts Enquiry*, I B Tauris & Co Ltd

Bernstein, L. (1976) *The Unanswered Question*,
Retrieved (2016) from
http://www.openculture.com/2012/03/leonard_bernsteins_masterful_lectures_on_music.html

Candy, L. (2006) *Practice Based Research: A Guide*, CCS Report: 2006-V1.0 November, University of Technology Sydney

Gann, K. (1997) *Just Intonation Explained*,
Retrieved (2016) from
<http://www.kylegann.com/tuning.html>

International Piano Supply (1997-2002) *Cents to Hz Conversion Chart*,
Retrieved (2016) from
<http://www.pianosupply.com/cents-hz/>

Lapp, D., R., *The Physics of Music and Musical Instruments*, Tufts University Massachusetts
Retrieved (2016) from
<http://kellerphysics.com/acoustics/Lapp.pdf>

Levine, M. (1995) *The Jazz Theory Book*, Sher Music

Manring, M. (2005) *Soliloquy - Extended notes*, Manthing Music

Manring, M. (1998) *Michael Manring [Instructional DVD for Bass]*, Hal Leonard Corporation

Music Calculator - Hertz
Retrieved (2016) from
<http://musiccalculator.com/#convert-hertz>

Oxford Dictionaries (2016) *Definitions for 'Harmonic' & 'Algorithm'*,
Retrieved (2016) from
<http://www.oxforddictionaries.com/definition/english/algorithm>

Pastorius, J. (2001) *Jaco Pastorius - Modern Electric Bass*, Manhattan Music Inc

Pear, D. (1999) *Bass Harmonics: New Concepts and Techniques*, Alfred Music

Prestia, R., Schaub, A. S. D. (1993) *Fingerstyle Funk with Francis Rocco Prestia*

Rawlins, R., Bahha, N. E. (2005) *Jazzology: The Encyclopedia of Jazz Theory for All Musicians*, Hal Leonard Corporation

Suits, B. H. (1998) *Frequencies for equal-tempered scale, A4 = 440 Hz*, Michigan Technological University,

Retrieved (2016) from
<http://www.phy.mtu.edu/~suits/notefreqs.html>

Suits, B. H. (1998) *Scales: Just vs Equal Temperament*, Michigan Technological University,

Retrieved (2016) from
<http://www.phy.mtu.edu/~suits/notefreqs.html>

Tension and Gauge Calculator

Retrieved (2016) from
<http://www.stringbusters.com/stringfaqs.asp#Calculator>

Tontechnik-Rechner – sengpielaudio, *Harmonics, Overtones, and the Fundamental, Calculations of Harmonics from Fundamental Frequency*

Retrieved (2016) from
<http://www.sengpielaudio.com/calculator-harmonics.htm>

Wooten, V. L. (2006) *The Music Lesson*, Berkley Publishing Group

Wooten, V. L., Bailey, S. (1993) *Victor Wooten & Steve Bailey: Bass Extremes*, Alfred Publishing Co.(UK)Ltd