8th Octave Overtone Tuning

by

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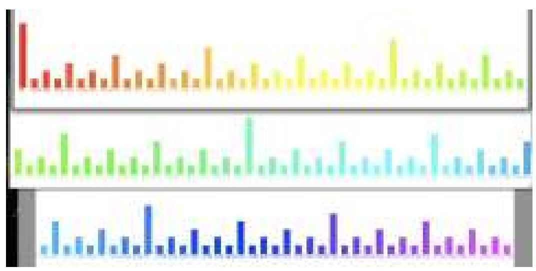

Nick Gideo created a chart of the first 256 overtones in the harmonic series, all compressed into the space of a single octave. The "x" axis represents the Harmonic number, and the "y" represents the "Prominence Factor," or how many times the harmonic has recurred throughout the natural harmonic series.

8^{th} Octave Overtone Tuning

By using only the information found in the harmonic series – also known as the overtone series – 128 distinct pitches are found outlined in its eighth octave. These 128 pitches constitute "definitive consonance." All the pitches found in harmonic timbre are considered consonant by definition because they are the parts that together constitute a single musical tone.

The timbre of a musician's sustained tone achieves a micro-harmony. Different pitches, parts of the whole, synchronize with each other to deliver what musicians call "good tone." There can be no dissonant intervals present in harmonically rich musical tone from this perspective.

The harmonics that are audible in a musical tone may be algorithmically developed to reach higher number ratios, which may then be reduced through octave displacement into a repeatable scale in every musical range.

> The primitive ear hears the tone as irreducible, but physics recognizes it to be complex. In the meantime, however, musicians discovered that it is *capable of continuation*, i.e. that *movement is latent in it*. That problems are concealed in it, problems that clash with one another, that the tone lives and seeks to propagate itself. They had heard in it, and extracted from it, the octave, the fifth, and the third (Arnold Schoenberg, Theory of Harmony, p. 313).

The harmonic series serves as a blueprint for musical connections and reception. It is a mode because the fundamental repeats most often throughout the harmonic series, and it is large enough a set of musical intervals as to not require modulation. Only the odd-number harmonics appear in the overtone series because the even-number harmonics are essentially duplicates.

> In the musical systems in which the tonic is permanent and consistently present to the mind of listeners, each note has, by itself, a significance, determined by the relation which binds it to the tonic. The melody is thus composed of a succession of sounds with a perfectly definite meaning, and, therefore, its significance is absolutely clear (Alain Danelieu, Introduction To Musical Scales, p. 21).

It was Andreas Werckmeister (1645-1706) of Germany's Harz Mountains in Thuringia who first recognized the natural origin of the irregular sized steps of *wohl-temperiert* (well-tempered) scales in the variegation effect of different sentiments, the positive consequence of emphasizing temporarily tonics on other overtones. Building on any note, other than the generating fundamental pitch (or its octave duplicates), creates a perceivable difference for the listener, in comparison, producing a different sentiment. For example, when mentally modulating to a temporary fundamental formed by the 57th harmonic, or "G," a major scale is easily constructed above it that sounds near identical to conventional equal temperament. This simpler "modulating," in the sense of giving different flavors to different regions of the single scale proposed, will be immediately rewarding.

Of course, one might decide to follow Ben Johnston's lead and implement extended just intonation, although it doesn't seem at all necessary when there is a treasure trove of fresh intervallic meaning newly available. Ben Johnston used the term "extended" to refer specifically to the use of overtones higher than the first six partials.[1] By the 1960s he focused extending "triadic just intonation no higher than the sixth partial," but decided to expand his aims in the 1970s in favor of a "more general audience with added higher partials 7, 11, 13,"[2] still later "to 17 and 19."

> I've greatly extended Harry Partch's system. I had formed some conclusions about just intonation by reading Helmholtz and other Helmholtz-influenced writings before I encountered Partch's writing, but Partch influenced me a lot; it was the first time I had encountered anybody trying to apply these ideas to composition. I generally explore a new aspect of extended just intonation with each piece, but what I've been working on for the last two years is so complex that I could never exhaust its possibilities in one or two pieces. With the kind of scale construction that I've used, I would have over one hundred notes in a chromatic scale. It's very unlikely that I'll get jaded with that kind of a palette (Ben Johnston, Perspectives Of New Music, Winter 1991, p. 180).

With few exceptions, all musical instruments emit harmonically rich tone, and they follow a particular series of numbers that can be easily graphed. Likewise, the human voice emits a harmonic tone when singing in a beautiful tone, as do plucked and bowed strings, and all wind instruments. The exceptions to the great majority of harmonic tones are deemed "inharmonic" because their physical bodies do not allow musical vibrations to move evenly throughout its mass; these include all metal struck instruments, notably the piano, Indonesian *Gamelan* idiophones, and tubular bells (also called "chimes"). Most arresting to the ear is the listening experience of *Hoomi* (or *chöömij*) throat singing – also called overtone singing – a feature in the music of Tuvans, Mongolians, and Tibetans, and especially virtuosic in the music of Sainkho Nymchalak and David Hykes.

> In the *Hoomi* tradition, singers produce a fundamental tone in the bass or baritone range, and then by extremely precise modulation of the abdominal muscles, chest, and the vocal apparatus—larynx, tongue, jaws, cheeks, and lips—project simultaneously a higher tone or tones, related in frequency to the fundamental tone by simple whole number ratios. Such higher frequencies are called 'overtones' or 'harmonics' (Theodore Levin, program notes for Hearing Solar Winds by David Hykes, 1982).

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[1] Ben Johnston "on the Performance Practice of Extended Just Intonation," from "Notes" to the score of String Quartet Number 9, referenced by John Fonville in several articles on Ben Johnston's practice.
[2] This information is extracted from handwritten additions by Ben Johnston to his *curriculum vitae* and given to the author, in the possession of the American Festival of Microtonal Music archive.

The trumpet, a dedicated overtone generator, illustrates well that the overtone series is actually an ascending series of increasingly smaller musical intervals. With any positioning of the pistons, the trumpet demonstrates clearly that a fundamental pitch gives way to its own octave through an increase in air velocity, a further increase of air produced, and a tightening of the embouchure. The trumpet doubles the fundamental pitch frequency for its second partial, doubles it again for its fourth partial, and doubles it still again for its eighth partial. The harmonics are in this sense plucked out of the fabric of timbre. Examples of a trumpeters' expertise playing higher harmonics may be heard in the playing of Arturo Sandoval and Doc Severinsen.

Ota Benga plays the molimo – the sacred pygmy trumpet—at the St. Louis World's Fair, 1904
American Museum of Natural History, New York

Perhaps the earliest examples of straight-up overtone tuning for a scale were the first used in musical culture. Batwa pygmies in the Congo are recognized for their vocal polyphony in overtones, and the San (Kung!) of South Africa famously play jaw harp through the 7th harmonic in their music. With the arrival of the Neolithic, cities introduced what is called eponymously "Pythagorean tuning" in Sumer and in Babylonia according to unearthed ancient prescriptive tablets, continuing which remained prominent until the Renaissance (c. 1440). In more recent times, Charles Ives favored a spiral of 22 perfect fifths for the majority of his later works, indicated through his notation system and his memos.[3]

The first interval to follow in the overtone series is an octave, which is why certain musical instruments are successful without an audible fundamental formant in the sound (e.g., French horn). The second octave of the overtone series adds the historic perfect fifth to the mix. The third octave of the overtone series initiates a major chord with an added "septimal" 7/4 minor seventh at 969 cents. The fourth octave of the overtone series forms a major scale of nine notes. The fifth octave of the overtone series lays out a chromatic semitonal scale of 16 notes. The sixth octave of the overtone series forms a 32-note quartertonal scale.

> [W]e might add that in the sixth octave, which contains the thirty-second through sixty-fourth harmonics, harmonics Nos. 33, 35, 37, and 39 are well represented by quartertones, although these more remote members of the series would not have so much practical importance (Ivan Wyschnegradsky, *Manuel d'Harmonie à quarts de ton*, 1933, trans. Ivor Darreg, 1976, p. 33).

The seventh octave of the overtone series delivers 64 notes of ever shrinking eighthtones. In 1973 Glenn Branca famously promoted 7th octave overtone tuning with his Symphony #3 "Gloria" - Music For The First 127 Intervals Of The Harmonic Series. To ease any confusion, Glenn Branca's 127 intervals include repeated composites to better simulate the organization of the series. 8th octave overtone tuning would double the new musical intervals vocabulary present in Glenn Branca's set, and they are available throughout the full range of singers and instrumentalists.

> In June 1982, I began a project to realize a pure tuning system for orchestral and chamber ensemble works. The tuning is a mirror reflection of the actual complex tones which make up the ideal harmonic structure of the physical wave energy produced by a vibrating string. This system necessitated the design and construction of instruments which could be tuned directly to the exact intervals of the first seven octaves of the harmonic series.

[3] The Ives Universe by Johnny Reinhard is published by the American Festival of Microtonal Music through its website: www.afmm.org, a chapter of which is devoted to Charles Ives's tuning preferences.

> This tuning makes it possible to determine and produce specific resultant (or differential) tones. Compositional structures have been determined by the logical geometric symmetry of the harmonic series. The series is a natural phenomenon which exists as a physical manifestation of symmetry and form. The existence alone of this language as music seems to indicate music as reflection of the movement of its own sound waves – not as symbolic, but a literal expression of dynamic symmetry in time. Ideally, every aspect of the tuning, instrumental design, compositional structure and performance should reflect the logic of the harmonic series (Branca, Symphony 3 liner notes, 1993).

For practical reasons, a full stop at the end of the eighth octave is completely understandable for it matches well the pitch range of human music making activity. It is appropriate for musicians to move from 12 notes to 128 notes foremost because the eighth octave of the overtone series contains half of the notes we use in standard twelve. Plus, conventional tuning has so successfully imprinted itself upon modern culture internationally that its hegemony supports a natural basis for eighth octave overtone tuning. Besides, any scale with up towards 128 notes offers composers and improvisers a multitude of successful combinations.

The eighth octave of the overtone series presents a sixteenthtone scale of 128 distinct notes. (See the end of this paper for a full list.) The measurement system that worked well for me over many years is the cent, equivalent to a 1200th of an octave, essentially the threshold of my pitch discrimination acuity.

> The choice of the cent as the base of a system of musical logarithms has been highly approved by all musicians interested in the scientific side of their art. It has been adopted by all modern acousticians who consider intervals as musicians do.
>
> Thus it has come about that, while the selection of some method of logarithmic representation of musical intervals was necessitated by a peculiarity of audition, the various values proposed for the base of the system have coincided with intervals of a particular musical scale (J. Murray Barbour, "Music Logarithms," p. 30).

Harry Partch (1901-1974) also valued cents to distinguish his 340 musical intervals, the smallest of which measure only 14.4 cents (Partch, Genesis Of A Music, p. 156).

> They give the adventurer his longitude and latitude and thus establish his whereabouts in that vast, barely explored sea which lies from the number 1 to the faraway shore of the number 2. The ratios on previous and subsequent pages, then, are the familiar or exotic islands that lie within the boundaries of this little-known sea (Partch, Genesis Of A Music, p. 83).

The ninth octave of the overtone series would add yet **another** 128 new pitches for a total of 255 distinct pitches per octave, extending the harmonic series through to the 511th harmonic. Edward Broms calculated all the ratios and cents values for the first nine octaves of the overtone series while a student of Joseph Maneri at the New England Conservatory, and tremendously inspired this work.

Arnold Schoenberg (1874-1951) intuited this brave new world of higher harmonics use in 1910, although regretfully, he lacked the physical capability to make the numbers audible. Schoenberg declared "that dissonances are the more remote consonances of the overtone series," a truth that no one earlier had dared speak (Schoenberg, p. 329).

EQUAL TEMPERAMENT:

AND ITS CLOSEST REPRESENTATION IN THE HARMONIC SERIES

Ascending Scale Order:	1	2	3	4	5	6	7	8	9	10	11	12
Harmonic Identity:	1	17	9	19	161	171	181	3	203	115	57	121
Harmonic Cents Value:	0	105	204	298	397	501	600	702	798	898	999	1103
Interval:	unison	m2	M2	m3	M3	P4	tritone	P5	m6	M6	m7	M7
Cents Deviation From Equal Temperament:	0	+5	+4	-2	-3	+1	0	+2	-2	-2	-1	+3
Octave Location Where Harmonic First Appears:	1	5	4	5	8	8	8	2	8	8	6	7

Overtones (overtone identities) each have a prominence factor associated with how often they appear as multiples in higher octaves of the harmonic series. After the first appearance of the 5th harmonic in the third octave of the overtone series, the 5th harmonic appears in each ensuing octave. For example, the 5/4 just major third measuring 386 cents recurs as the 10th, 20th, 40th, 80th, and 160th harmonics. The 5th harmonic sounds too flat to fairly represent the equal tempered major third of 400 cents, although the 171st harmonic of the overtone series in the eighth octave is only a single cent sharper than its equal temperament counterpart. To the modern ear, the 5th harmonic major third of 386 cents sounds inaccurately low. Heinrich Schenker (1868-1935) believed the 5th harmonic constitutes the intellectual boundary for the ear's capability to distinguish between overtones.

> The human ear can follow Nature as manifested to us in the overtone series only up to the major third as the ultimate limit; in other words, up to the overtone which results from the fifth division. This means that those overtones resulting from higher subdivisions are too complicated to be perceived by our ear, except in those cases, where the number of divisions is a composite which can be reduced to a number representing the lowest, perceivable, order of division by two, three. Or five. Thus six can be recognized as two times three or three times two; nine as three times three; ten as five times two, etc., whereas the overtones, 7, 11, 13, etc. remain totally extraneous to our ear (Schenker, Harmony, p. 25).

Composer La Monte Young famously abhors using the 5/4 major third interval in his music, but considers the true number of notes to be infinite.

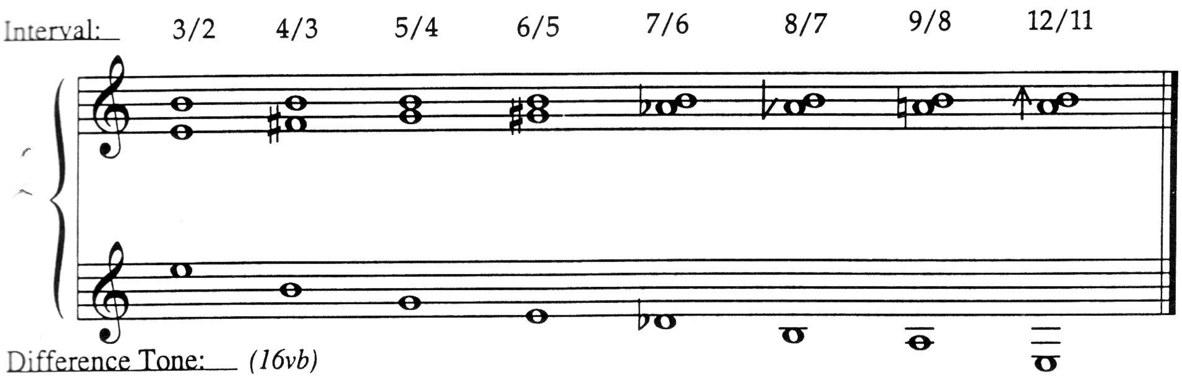
> Of course there is no limit upon the number we can eventually squeeze into an octave, because we don't necessarily hear them as one coming after another, filling up an octave. We hear them as various relationships to a pitch we have established very clearly in our ears and minds (La Monte Young in Richard Kostelonetz Interview, 1970).

Like Harry Partch, but even earlier, Mexican composer Julián Carrillo (1875-1965) pioneered microtonal exploration through original compositions and instrument design. Carrillo famously built a sixteenthtone harp in 1895 for his microtonal music, and developed a new music philosophy he called, *Sonido Trece* ("Thirteenth Sound"). The name, Thirteenth Sound, refers to his celebration of the discovery that he could produce a clean sixteenthtone above an open string by placing his finger on the nut of his violin strings, leaving him to forever mull over its myriad implications. Nominated for a Nobel Prize for his research on harmonic string nodes, Carrillo confidently postulated the validity for the ear of intervals as small as the 128thtones lined up in the 11th octave of the harmonic series, though, he never used it in his written music. Carrillo regularly pointed out the contradiction that contemporary performance practice did not reflect the peculiarities evident in the overtone series, but did state for the record his expectations for *Sonido Trece*.

> As my musical studies advanced, I discovered the means of producing 4,000,000 tones perfectly distinguishable by the human ear.
>
> If the biological development of the ear continues proportionately with the conquest of new tones, in the not-too remote future human beings should be able to distinguish the infinite number of pitches postulated in the Thirteenth Sound system many years ago (Carrillo, *Sistema General de Escritura Musical*, 1957, trans. by Bellamy, p. 471).

Ironically, the default minor third candidate in the overtone series is sonically identical with the manner in which modern pianists, string players, and wind players already play it; it is the 19th harmonic. It measures 298 cents, only two cents shy of the minor third universally employed in the standard twelve (the same schismatic distance with which we reduce the 3/2 perfect fifth to work in equal temperament). The 19th harmonic precedes the 20th harmonic (a multiple of the 5/4 just major third in the fifth octave of the series) repeatedly, serving more to promote the major third harmonic rather than to distract from it. The harmonic series is nature's fullest chord, one truly both major <u>and</u> minor, with bouquets of many other sentiments. Additionally, there is a bandwidth of minor thirds to choose from if interested in alternatives to the now almost pedestrian 19th harmonic, these include a diminished minor third (149th harmonic at 263 cents), a low minor third (151st harmonic at 286 cents at 320 cents), a small minor third (75th harmonic at 275 cents), a low just minor third (153rd harmonic at 309 cents), a high just minor third (77th harmonic at 320 cents), a large minor third (155th harmonic at 331 cents), and a big minor third (39th harmonic at 342 cents).

Musicologists, theorists, and musicians often explain the traditional just minor third as "artificial" in origin, existing through a secondary "undertone series" imagined as the mirror inverse of the harmonic series. Jon Catler demonstrated in his original composition *Sleeping Beauty* how to produces a melodic mirror of the overtone series through an electronic emphasis on difference tones on electric just intonation fretted guitar. The reciprocal series begins as the difference tone produced below a harmonic fifth on "E" in the treble range. It seems poetic that five out of the eight intervals used to create the melodic series of difference tones to mirror the natural overtones are themselves derived from the imagined undertone series, which to include the 4/3 "perfect fourth," the 6/5 "just minor third," the 7/6 septimal minor third (famously heard in the children's descending "nah-nah" chant, though better explained as the 75th harmonic of 275 cents), the 8/7 large major second (which was used by Harry Partch as a motif interval for "water" in his large stage work, *Water! Water!*), as well as the three-quarters of a tone 12/11 interval (often heard at the end of Egyptian maqamat phrases.



Using intervals from a presupposed undertone series as a source for scale tones is as old as ancient Greek. If we measure up from the 5th harmonic (5/4) to the sixth harmonic (6/5), then we have the distance of the just minor third at, popular in *a cappella* Renaissance music and used prominently in the ancient Greek chromatic genus.[4]
The 6/5 just intonation minor third of 316 cents is constructed by the subtraction of a 5/4 major third interval from a 3/2 perfect fifth (702 – 386 = 316 cents). René Descartes (1596-1650) determined in the Renaissance that the 6/5 just minor third appears "to be a mere 'shadow' of the major third because it has no basis in nature" (Descartes, p. 26).

There appears to be little direct evidence of a natural undertone series operating on the same footing with the natural harmonic series of overtones, *per se*. There are some remarkable "under" sounding tones, such as the subharmonics as produced on the violin by Mari Kimura, who produces intervals of an octave or smaller through bow

4 Remarkably, the ancient Greek enharmonic genus, the famed favorite of Euripides, employed higher overtone ratios in its tuning schemes than used in later eras in order to allow for quartertones discovered in the sixth octave of the overtone series.

twists and pressures.[5] *Hoomi* specialist Timothy Hill can generate at least four undertones from a single fundamental, but does not feel that they combine with normal singing and the overtones they produce. Just intonation composer Toby Twining modulates sustaining an overtone produced harmonic only to mentally renumber it to create new fundamentals in his composition *The String Room* (2010) for vocal quartet and cello. While sustaining a 7th harmonic – heard as a whistling – over several measures, an ascending walking bass becomes audible by virtue of the reinterpretation of the harmonic's role toward a given fundamental. Undertones have been successfully investigated in animals, specifically guinea-pig and chinchilla ears, by recording cochlear-microphonic potentials and sound pressure at the eardrum (Peter Dallos' "Origin of Subharmonics in the Peripheral Auditory System," 1966, p. 1252). It appears the animal's ears provide deeper pitch receptors, independent of the sounded higher pitches.

My suggestion is to cease the use of pitches derived from undertone speculation to calculate musical scales composed of whole number ratios; they impede the resonance of the harmonic series and belie its hidden character. Paul Hindemith (1896-1963) dismissed any serious discussion of an imaginary undertone series, a position easier to embody once twelve-tone equal temperament was quite universally accepted as a norm.

> It seems to me repugnant to good sense to assume a force capable of producing such an inversion … [The undertone series] can never have for music the same significance as the overtone series … This 'undertone series' has no influence on the color of the tone, and lacks the other natural advantages of the overtones series … (Hindemith, the Craft of Musical Composition, p. 78).

As a metaphor, imagine for a moment you are sandpapering a reed for a woodwind instrument. It is critical for best results to sandpaper in the direction of the grain in order for the reed to vibrate freely. The overtone series richness in the tone of the woodwind is proportionately enhanced when a reed is sanded "with the grain."

A new character in the musical interval pantheon is the perfect fourth of 43/32 measuring up to 512 cents. There simply is no 4/3 "just perfect fourth" of 498 cents in the overtone series! It can only be achieved as an impression left upon a listener immediately following the temporary establishment of a perceived tonal center in ongoing music, a temporary tonicism. It is sort of like seeing a rainbow in the sky; the rainbow seems real in its depth but you can not measure by it.

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[5] Michael Vincent wrote more detail than has been offered by Mari Kimura as pertains to subharmonics in his Contemporary Violin Techniques: The Timbral Revolution (2003). "Perhaps the newest bowing technique that has been increasingly appearing is Subharmonics…the use of extreme pressure to the bow stroke and careful placement across the string(s), which creates a variety of pitches sounding below the fundamental of an open string. For example, by bowing the G string precisely at the point where the octave is divided equally (midpoint of string) and applying overpressure to the bow stroke, the resulting sound will be a G one octave lower than the G string. If one bows the G string on a string divided at the 1/3 point, the result will produce a low D (a twelfth below the open G). This will be consistently produced at any harmonic node when overpressure is applied."

While historically institutionalized in the plagal cadence, the 4/3 just perfect fourth is simply not present in the actual overtone series, a fact which is acoustically manifest in the bassoon's sound. The low "D" of the bassoon famously blows sharp and works in a weak fashion, making it among the least reliable notes on the instrument. To counter this phenomenon, a professional caliber bassoonist remodels the inside of the throat cavity in order to compensate by implying a fundamental pitch in the sound. Accordingly, the essence of achieving a rich tone on a bassoon is to improve the partials inherent in the tone produced, according to Paul R. Lehman in his "Harmonic Structure Of The Tone Of The Bassoon" in the Journal of the American Acoustical Society.

The "perfect" fourth interval achieved through the 43rd harmonic at 512 cents is both greater than <u>and</u> equal to antiquity's 4/3 at 498 cents. Traditionally, the "perfect" fourth ratio is achieved by the subtraction of the perfect fifth from the octave: (2/1 – 3/2 = 4/3). The musical interval 4/3 is a remainder, the shadow of the perfect fifth, and most assuredly is not locatable in the overtone series, even as the Pythagorean ditone is present as the 81st harmonic.

$$\frac{43}{32} \geq \frac{4}{3}$$

Of course, it is also possible to calculate the equal tempered perfect fourth of modern practice as the 171st harmonic, which measures only a single cent higher than the "perfect fourth" of equal temperament. However, the sonorous 43/32 fourth succeeds fully as a "new" perfect fourth preference based on now numerous professional musical experiences. Additionally, there is a bandwidth of alternative "perfect" fourths to choose from. Incredibly, the conventional equal temperament tritone divides the octave into two equal halves, is a featured modulation interval in jazz, and is the 181st harmonic the overtone series' eighth octave.

La Monte Young is that rare composer working exclusively with higher harmonic tuning. While a student at Los Angeles City College (1955-1956), he received regular private lessons in music composition and counterpoint from Arnold Schoenberg's pupil and assistant Leonard Stein (1916-2004). A declared autodidact, Schoenberg's full adoption of twelve tone equal temperament as the new normal negates any need to explore seriously a dated tonal theory. Apparently, "undertone series theory," as promoted by Hugo Riemann and Harry Partch, was not transmitted to La Monte Young.[6]

Similarly, Arnold Schoenberg influenced my thinking through Patricia Carpenter at Columbia University, another Schoenberg pupil. We never spoke of an "undertone series" in her Theory pro-seminars. Presciently, my 1984 paper written for Professor Carpenter, "Arnold Schoenberg's Conception of Tonality," concurs with Schoenberg's *raison d'etre*.

[6] La Monte Young lists Richard Maxfield and Karlheinz Stockhausen as composition teachers in his *curriculum vitae* in addition to Leonard Stein.

> My attempts to explain the problems psychologically, or on practical grounds, or by the overtones, will at least be of use to a future theorist, even if he builds on principles different from mine (Schoenberg, p. 328).

La Monte Young determinedly explored musical landscapes previously only intuited by Schoenberg, and transmitted through Leonard Stein. La Monte Young's tuning system amplifies Schoenberg's notion that the chord is a "synthesis of the tone" (Schoenberg, p. 26).

> In January 1989 I felt extremely inspired to begin to listen to intervals and compose within the range 112 to 144 of the harmonic series, by further utilizing the capabilities of the Rayna synthesizer. And thus, *The Symmetries in Prime Time from 112 to 144 with 119* were born (1/1, volume 5, no. 4, p. 7).

> In *The Symmetries in Prime Time from 112 to 144 with 119* the Rayna synthesizer has made it possible to realize intervals which are derived from such high primes that, not only is it unlikely that anyone has ever worked with these intervals before, it is also highly unlikely that anyone has ever heard them or perhaps even imagined the feelings they create (La Monte Young's liner notes for a 1990 concert, p. 7).

> The prime frequency identities set forth in this "Symmetry" produce some of the most complex harmonic relationships I have ever worked with yet the combination generates an immediately accessible composite waveform that is extraordinarily vibrant and creates an ecstatic paradisiacal state of primordial time (La Monte Young's liner notes for a 1990 concert, p. 9).

Kyle Gann calculated by ear ten of the twelve notes to the octave that La Monte Young used in *The Well-Tuned Piano*, so La Monte coughed up the other two.

> Johnny Reinhard: Is the tuning system for your keyboard public knowledge?

> La Monte Young: No. I've been pretty secretive about it. I give hints about it here and there, and of course, if you go to my score show and study it hard, I think you should be able to figure it out (Ear Magazine, vol. 7, no. 5, 1982-1983, p. 4).

Some of the overtone ratios make only rare appearances in the almost 6 hours of continuous music, although 11 octaves of the overtone series are represented. Kyle Gann's further research noted that one note was never actually heard in the recording!

> On the Gramavision recording of *The Well-Tuned Piano*, the 441/256 "C#" occurs only on the fifth CD, in the sections indicated as being in 'The Elysian Fields.' Young rarely uses "G#" 1323/1024, and the pitch doesn't occur on the recording at all (a frustrating omission for those trying to tune the entire scale from the disc). Unused pitches, however, do add resonance, since the entire scale consists of overtones of a low "Eb" ten octaves below the lowest "Eb" on Young's Bösendorfer grand (Gann, pre-published article on *The Well-Tuned Piano* given to the author).

> *The Well-Tuned Piano* is an unparalleled exercise in attunement to sound. Each large section builds up from sparse, melodic notes to dense, stochastic clouds with such gradualness that intense listening is needed to catch the process in motion. Here, form followed acoustic necessity: the flow of momentum marshaled the vibrations of air in the room, slowly making the ear aware of sounds that weren't actually being played. The play of combination and difference tones created astounding aural illusions (Gann, The Village Voice, June 6, 1987).

The Well-tuned Piano Tuning In Ascending Keyboard Order

[Two of the ratios – bolded - are intentionally out of linear order for performance reasons]

RATIOS	1/1	567/512	9/8	147/128	21/16	**1323/1024**	189/128	3/2	49/32	7/4	**441/256**	63/32
CENTS	0	177	204	240	471	444	675	702	738	969	942	1173
OCTAVE LOCATIONS	1	10	4	8	5	11	8	2	6	3	9	6

As part of an interview with La Monte Young and his artist wife Marian Zazeela for the now defunct Ear Magazine, we recorded hours of unpublished discussion and banter on January 23, 1982. As it happens, I was a guest editor along with Tui St. George Tucker and Robert Jurgrau of Ear's "Microtonal Issue," and I wanted to learn of La Monte Young's and Marian Zazeela's respective reactions to the impressive "harmonic clouds" that I experienced during live performances of *The Well-Tuned Piano* in New York City, sitting on floor mats without my shoes.

The harmonic clouds are naturally amplified acoustic ephemera, specifically the result of harmonics tuning, combination sounds that result, natural beatings of particular pitches and their combinations, the performing artists' inspired sense of rhythm, the room's acoustics; all in subtle chain reactions with each other, floored me. I had experienced them earlier at New York concerts. Anecdotally, I personally observed how harmonic clouds completely transformed an unfamiliar young boy in the audience, who reacted emotionally to the harmony of the clouds as I felt. Remarkably, as the harmonic clouds shifted, the boy's countenance – and mine – unfroze in synch.

Harmonic clouds sound markedly louder than the hammered notes played by a pianist's fingers, as to disguise them completely. *The Well-Tuned Piano* was not originally composed to produce "clouds" in 1964 when it was played on an upright piano. Marian Zazeela recalled it was in 1976 when a Bösendorfer piano was designed to play the piece in New York that they both recognized and acknowledged the existence of the "clouds" in *The Well-Tuned Piano*.

JR: How important is the cloud as compared to the fundamental notes of the keyboard?

LY: I think that the cloud is just as important as the fundamental notes and that if you miss either one I think you're missing too much. I think it's important to hear both. And one of the challenges in recording the work has been to try to capture both the cloud and how fast I play, which I find tends to get lost…

JR: In the clouds (laughs)!

LY: (laughs)! Right! It goes off into the clouds. … When we record the piano, I try to record it very close-miked, so that I have all of the basic elements that went into producing the clouds. Then when you play it back in another room it will create a cloud in that room as opposed to trying to record the cloud in the room it was recorded in and transferring that cloud to another room; which, I think doesn't work (Conversation With La Monte Young and Marian Zazeela, Ear Magazine, 1982-1983, p. 4).

As a result of the close mikes to the piano body, the Gramophone commercial release is profoundly dwarfed by the live experience.[7]

JR: You like the mikes to be placed right over the keyboard strings.

LY: Right. It's very close. And then when you play that tape back in a totally different room, you don't have to deal with the noise and acoustics of the first room. You get a new cloud in the new room, which is basically very similar, and it's naturally acoustically the same because it's created from the same notes. That is, from the harmonic perspective, it's acoustically the same. It's acoustically different in every different space, because every different space has a different set of resonant properties.

JR: And you have a 'cloud'?....

LY: Right and the clouds are very static. Each cloud is usually created from a limited set of tones that I play in various permutations and combinations extremely fast.

JR: Now you are in just intonation. That's the category we're given.

LY: Mainly the category I work in is just intonation (Conversation, Ear Magazine, 1982-1983, p. 4).

La Monte Young's tuning of *The Well-Tuned Piano* is considered by its composer to be in just intonation for it was rationalized in 7-limit just intonation. Evidently, La Monte Young did not inherit the article of faith that requires using scale tones chosen from an imagined undertone series. The imperative here is to distinguish just intonation tuning systems from the 8th octave overtone tuning I have proposed for they are by no means identical. Just intonation tuning does not draw its musical intervals exclusively

[7] In the interest of full disclosure, I was La Monte Young's archivist and administrative assistant for two years following the 1982 interview published in Ear Magazine. Additionally, I did some editing on liner notes and on La Monte Young's *curriculum vitae*, pasted up reviews, and purchasing ladybugs botanic gardens.

from the overtone series; it incorporates an obligatory second series of numbers imagined as a reciprocal "undertone series" to the much more perceivable overtone series. And it defines itself through self-imposed "limits" designated by a specific harmonic.

> Now a just intonation system, no matter what limits you put on it…… and you certainly can place limits on it……is infinite. Each set is infinite. You can use a subset, any subset you like, and that's what you have to do if you're going to make music…..because obviously you can't deal with an infinite set. But you do have as a total an infinite set each time you have a just intonation system (Ben Johnston in Walter Zimmermann's "Desert Plants," 1980).

The first title with the term "just intonation" was authored by General Perronet Thompson (1783-1869), according to his librarian, V.K. Chew.

> The tract 'Principles and Practice of Just Intonation' in which General Thompson expounded his views, is a pleasure to read, as remarkable for the vigour with which he belaboured the 'temperers' as for the enthusiasm with which he defended his solution to the problem of playing in just intonation. 'Temperament', he says, 'is a device for saving the trouble of playing in tune by playing out of it; for playing in a variety of keys by playing in no key at all; for trying how much untunableness the ear can be educated to bear, instead of how much harmony it can be educated to demand' (Thompson in V.K. Chew, "Blowing Up Temperament," p. 34).

In contrast to just intonation, 8^{th} octave overtone tuning is like an Aeolian harp because every pitch in this complexity belongs to the *gestalt* that is the sung human vocal sound. Following simple harmonics usage, such as with Rhaetian alphorns, the next advance in music history comes in the Neolithic with (the unfortunately named) Pythagorean tuning comprised of 3-limit just intonation, its tones drawn from an intellectual spiral of fifths. Meantone tuning is the Renaissance temperament of 5-limit just intonation. Terry Riley's music sometimes samples the vocabulary of 7-limit just intonation, while, Harry Partch famously capped his music at 11-limit just intonation. Contemporary guitarist Jon Catler is a virtuosic rocker in 13-limit just intonation. The greatest difference in audition between just intonation and higher harmonic overtone tuning…is the sound heard experientially due to the spectacularly different intervallic content of the systems.

We have now evolved intelligent attempts to reconcile the different systems with each other, albeit for measurement purposes, connecting all whole number ratio activity to the category of just intonation tuning through the power of infinity, and leaving everything else to temperament. David B. Doty, the former editor of 1/1: The Quarterly Journal of the Just Intonation Network in San Francisco, cleverly raised and then answered his own question as to the proper definition of just intonation in an essay in Polyphony:

> What is 'Just Intonation?' This term applies to any tuning system in which all of the intervals may be represented by ratios of whole numbers, with an implied preference for the simplest ratios that are musically useful (Doty, Polyphony, August 1983, p. 38).

David Doty understandably wanted to build a bigger tent for his readership by gently sidestepping any requirement for using the speculative undertone series. Following the celebrated idiosyncratic certainty of Hugo Riemann in an undertone series inimical to an overtone series, belief in an undertone series was to become an article of faith for composers Harry Partch and Ben Johnston, Kyle Gann and Jon Catler, but not to La Monte Young…or Glenn Branca, who comes closest to understanding the potential presented by the microverse that is evident in the harmonic series.

> You see, it's a non-linear system, and because this system is also the vibration of a string, within the vibration of a string **is** the entire harmonic series. A string vibrates in at least 256 modes all the time. These modes, all vibrating at the same time, are inter-penetrating in a way that creates the sound that we hear. It's all of those sounds, ringing at the same time, that give what we perceive as a single sound, but we don't hear a single sound, we're hearing a resonance that is the result of multiple sounds, an interpenetration of non-linear vibration. It's fabulous stuff" (Glenn Branca, "Interview With Glenn Branca" by Brian Duguid on the Internet).

Schoenberg earlier lamented the paucity of musical idealists to accept the necessary challenges in light of twelve tone equal temperament's general acceptance.

> Until a short time before [musicians] had been on the right track, as, following the dictates of the material, they imitated the overtones. But then they tempered the system, and the system tempered the burning urgency to search. They had concluded a truce. But they did not rest in order to rearm and regroup; they rested in order to rust. The tempered system was an emergency measure, and an ingenious one, for the emergency was grave and the measure ample. It was an ingenious simplification, but it was a makeshift. No one, having wings, would rather fly in an airplane. The airplane is also an ingenious makeshift; but if we could fly merely by an act of will, we should gladly do without the machine. We ought never to forget that the tempered system was only a truce, which should not last any longer than the imperfection of our instruments requires. I think, then, contrary to the point of view of those who take indolent pride in the attainments of others and hold our system to be the ultimate, the definitive musical system – contrary to that point of view, I think we stand only at the Beginning. We must go ahead! (Arnold Schoenberg, Theory of Harmony, p. 314).

Exploring musical relationships in my new preferred scale was accomplished without the aid of machines, other than my trusty bassoon. My aesthetic interests evolved from cultural norms, to an appreciation of microtonal music, to polymicrotonal music situations wherein distinctive tunings interact in a single piece of music. Among some other musicians that have been seduced by polymicrotonality are Charles Ives, Iannis Xenakis, Jean-Etienne Marie, and Peter Thoegersen. As a life-long specialist in microtonal bassoon performance playing in a multitude of different tuning systems, I learned to internalize several different tunings. While generally true for most professional musicians, a bassoonist must "hear" musical intervals in the mind in order to reliably produce the correct tone, pitch, and its trajectory (the angle with which the pitch is approached). The professional bassoonist runs melodies through in the head before a listener hears anything played.

In the summer of 2010 I began carefully plotting out of 128 pitch harmonic series scale with secure and reliable bassoon fingerings invented to service throughout the instrument's entire range. Essentially, I sought the idiosyncratic physical shapes for my fingers necessary to produce each particular pitch. During my university and conservatory studies I worked diligently with the Korg Model WT-12 chromatic tuner for reliable pitch accuracy, a quartz memory tuning machine recognizable by its singular ability to "sing" out user definable microtonal pitches. (Unfortunately for younger musicians, this model has long since become discontinued.) It feels as if I have since graduated to a deeper understanding of sound and how to produce it on the bassoon. Since I had earlier published original fingering charts for bassoon for seven-tone equal temperament (equiheptaphonic), twenty-four tone equal temperament (quartertones), and 31-tone equal temperament (tricesimoprimal), I already possessed several of the necessary fingerings because they were previously obtained in other contexts (Reinhard, ed., Pitch, volume I:4).

Choosing A=440 as the fundamental for generating harmonics might seem arbitrary in the abstract, however the 128 note scale built on "A" is both resonant throughout the instrument and technically manageable on the woodwinds, while traditionally present on an open strings for tuning purpose. The symphony orchestra traditionally tunes to the harmonically rich "A" of the oboe.[8] And "A" is more than the first letter of the alphabet; it is the first pitch from which I measure all other musical intervals on my professional model Püchner bassoon.

The bassoon offers a comfortable access to the overtone pitches because the very fabric of the instrument's tone is based on the note "A."[9] Musical tones are a construction of an overtone chord in microcosm. Bassoons sound beautiful playing in overtone tuning, better than it does in equal temperament, as if to announce that overtone tuning is its true identity. The musical successes of performances in 8th octave overtone tuning have been uniformly rewarding, but please allow me to be among the first to demand scrutiny.

It remains a paradox that while improvisation is paramount in my overtone-tuned quartet, *Vibra* (2011) for violin, double bass, and two bassoons,[10] the ensemble innocently created the illusion that the piece had been completely notated. On our music stands was a simple one-page roadmap, with no pitch indications. When, by chance, I heard an especially notable harmony achieved through improvisation in *Vibra*, I initiated vocalizations three times on the phoneme "ah" on the exact pitches last played by the musicians on their instruments, thereby retaining the harmony as a single chord

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[8] Harry Partch tuned to a "G," Ben Johnston to a "C," La Monte Young in *The Well-Tuned Piano* to an "Eb" far below human hearing, and Jon Catler to an "A" matched to the 60 cycles of North American electricity.

[9] The bassoon only requires a small piece of adhesive tape to cover a tiny portion of the bassoon's "B" hole in order to facilitate the 19th harmonic to perfection with the conventional fingering for "C." The tape is the one physical change necessary to play any of the other 128 differing notes in each octave.

[10] *Vibra* was premiered on May 15, 2011 at the Church of St. Luke in the Fields, in New York City's Greenwich Village by Sara Schoenbeck and Johnny Reinhard (bassoons), Richard Carr (violin), and Joshua Morris (double bass).

sustaining throughout the length of original poems. Also, in *Vibra*, the double bassist has a *scordatura* tuning with the open "A" string equivalent to A=440, and with the fourth above on the next string raised 14 cents higher, the highest string is tuned 28 cents higher than usual, a smidgen higher than an eighthtone higher than per usual. The lowest string is lowered further to a pre-determined size. An incredible coherence was maintained, and was admittedly aided by the participation of wonderfully matched musicians. In addition to learning many new fingerings, certain familiar intervals were simply not played by the musicians (e.g., 4/3, 6/5, the wrong quartertones, glissandi). In retrospect, I can only admit the net effect created the false impression of compositional specificity, perhaps in no large part due to the inserted poems.

August 4, 2011 brought the good luck of another exemplary example of 8th octave overtone tuning, this time with a quintet titled *Sagittal Daze* for clarinet, bassoon, trombone, laptop, vocalist and percussion at Patch Adams' Gesundheit! Institute in Hillsboro, West Virginia.[11] The musicians informally called the 8th octave overtone tuning simply "128" for rapid recognition of the strict harmonic tuning mutually undertaken.

We have even successfully performed established composers, such as Nicola Vicentino (three enharmonic excerpts from 1555), and Igor Stravinsky (1882-1971), specifically his miniature *Lied Ohne Name* (1918), a one-page scored duo for two bassoons played in 8th octave overtone tuning. I chose intervals from the harmonic series that best represented Stravinsky's published notation, lower number harmonics were chosen when it was possible, staying true to the contrapuntal intentions of the melodic lines. There were different Eb's to choose from, and different F#'s as well; however it was not difficult to make rational choices to satisfy Stravinsky's pitch functions. While the Stravinsky performance was anecdotally captivating to the audience in higher harmonic overtone tuning, playing this short piece in conventional equal temperament sounds awful, creepily devoid of musical import, and a good reason to ignore the piece altogether.

No one contests that Igor Stravinsky originally conceptualized this miniature in conventional twelve-tone equal temperament. However, when asked by a journalist, "Is any musical element still susceptible to radical exploitation and development?," Stravinsky responded thoughtfully:

> Yes, pitch. I even risk a prediction that pitch will comprise the main difference between the 'music of the future' and our music (Stravinsky, "Memories And Commentaries," 1970, p. 115).

[11] *Sagittal Daze* was premiered successfully on August 4, 2011 at the Gesundheit! Institute as part of the Xenharmonic Praxis summer camp of microtonal music. The performers include the Michael A. Garman (clarinet), Johnny Reinhard, Steven Kandow (trombone), Douglas Blumeyer (laptop), and Nick Gideo (voice and percussion). Douglas Blumeyer was able to calculate pitch up to the 11th octave in his gamut. We each played a different subset of the 128 possibilities.

Igor Stravinsky's musings gave me the idea to sharpen the intonational lenses on Stravinsky's notation. I merely removed all semblances of temperament, choosing instead to use the harmonic series exclusively. Stravinsky was greatly influenced by Arnold Schoenberg, and entered a serial period in his later mature period.

> What has not yet been attained is what is worth striving for. What has already been attained is a system that was able to accommodate some overtones with considerable exactness, some others rather inexactly. What has been attained is the almost exhaustive combination of all possibilities of this system by the unconscious ear of the creative musician, by his intuition. Still absolutely missing is the correct identification of the relation between what has been attained and what is still to strive for. We must yet strive for everything that is left over: the precise accommodation of all overtones, of a new system, the thorough combination of resulting relationships, the invention of instruments that can bring that music into being,…and so forth (Schoenberg, p. 320)

A new music is waiting to be composed. In the mean time, improvise.

128 Notes of Eighth Octave Overtone Tuning

Harmonic	Cents	Name of interval
1	0	unison
129	13	sixteenthtone
65	27	eighthtone
131	40	smaller quartertone
33	53	quartertone
133	66	large quartertone
67	79	small semitone / 3-eighthtones
135	92	minor semitone
17	105	Bb, major semitone
137	118	large semitone
69	130	big semitone
139	143	small three quarters of a tone
35	155	large three quarters of a tone
141	167	diminished whole tone
71	180	small whole tone
143	192	minor whole tone
9	204	B, major whole tone
145	216	large whole tone
73	228	whole plus eighthtone
147	240	5ET diesis
37	251	five quarters of a tone
149	263	diminished minor third
75	275	low minor third
151	286	small minor third
19	298	minor third
153	309	low just minor third (referencing 316)
77	320	high just minor third (referencing 316)
155	331	large minor third
39	342	big minor third
157	354	neutral third
79	365	tiny major third
159	375	eighthtone flat major third
5	386	C#, just major third
161	397	ET major third
81	408	Pythagorean ditone

163	418	large Pythagorean ditone
41	429	Db
165	440	small quartertone sharp major third
83	450	quartertone sharp major third
167	460	tiny fourth
21	471	low fourth
169	481	minor fourth
85	491	major fourth
171	501	ET perfect fourth
43	512	perfect fourth, D
173	522	fourth plus comma
87	532	fourth plus a fifthtone
175	541	fourth plus small quartertone
11	551	eleventh harmonic
177	561	tiny tritone
89	571	low tritone
179	581	minor tritone
45	590	D#
181	600	Eb, ET tritone
91	609	large tritone, Eb in tonal music
183	619	big tritone
23	628	eighthtone high tritone
185	638	quartertone and sixteenth flat dominant
93	647	quartertone flat dominant
187	656	tiny dominant
47	666	small dominant
189	675	eighthtone low dominant
95	684	irregular perfect fifth
191	693	sixth comma flat fifth
3	702	perfect fifth
193	711	poodle fifth
97	720	large fifth
195	729	howling dominant
49	738	sixthtone high dominant
197	746	three quartertones high perfect fifth
99	755	quartertone high perfect fifth
199	764	quartertone and 16^{th} tone high fifth
25	773	quartertone and eighthtone high fifth
201	781	almost minor sixth
101	790	tiny minor sixth
203	798	ET minor sixth

51	807	minor sixth
205	815	just minor sixth
103	824	large minor sixth
207	832	big minor sixth
13	841	thirteenth harmonic
209	849	quartertone high minor sixth
105	857	quartertone plus minor sixth
211	865	almost major sixth
53	874	tiny major sixth
213	882	small major sixth
107	890	just major sixth
215	898	ET major sixth
27	906	major sixth
217	914	sixthtone high major sixth
109	922	eighthtone high major sixth
219	930	eighthtone and 16th tone high major sixth
55	938	large major sixth
221	945	big major sixth
111	953	three quartertone sharp major sixth
223	961	small harmonic seventh
7	969	harmonic seventh
225	977	large harmonic seventh
113	984	tiny minor seventh
227	992	small minor seventh
57	999	G, minor seventh
229	1007	large minor seventh
115	1015	big minor seventh
231	1022	double perfect fourth
29	1030	eighthtone high major seventh
233	1037	eighth- and 16th tone high minor seventh
117	1044	three-eighths flat major seventh
235	1052	quartertone flat minor seventh
59	1059	tiny major seventh
237	1066	diminished major seventh
119	1074	eighthtone flat major seventh
239	1081	small major seventh
15	1088	major seventh
241	1095	large major seventh
121	1103	ET major seventh
243	1110	big major seventh
61	1117	Ab, large minor seventh

245	1124	eighthtone plus major seventh
123	1131	leading tone major seventh
247	1138	sharp leading tone major seventh
31	1145	hyper leading tone major seventh
249	1152	quartertone flat octave
125	1159	three-eighths flat octave
251	1166	eighthtone flat octave
63	1173	small octave
253	1180	comma flat octave
127	1186	dipped octave
255	1193	preoctave

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