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Appendix I: Microtonality in 20th Century Western Art Music: A Selective Overview

1 Introduction and definitions

The question of whether microtonality could form the basis of a new avant-garde movement, one for the 21st Century, is frequently discussed by musicologists, music philosophers, and composers these days.[41] As of now, it appears that this potential avant-garde is still in its infancy, due in no small part to the lack of a coherent tradition of microtonal music. The application of microtones in 20th Century Western-art music has predominantly been a matter of individual systems and solutions by each respective composer. In retrospective it is nevertheless possible to identify certain characteristic threads of microtonal aesthetics and techniques that were common to various composers over the course of the past century.

The Austrian composer Georg Friedrich Haas (b.1953) suggested four different basic approaches to microtonality:[42]

- The application of additional pitches to the familiar twelve-tone chromatic system in equal temperament. This leads to equidistant sub-divisions of the octave generating a number of pitches either larger or smaller than twelve (for instance, the 19-tone equal temperament system which contains 19 equidistant pitches per octave, or the 10-tone equal temperament system containing ten pitches per octave). This approach also includes equidistant sub-divisions of intervals other than the octave.
- The creation of pitch systems whose (just) intervals are based on the proportions of the overtone series.
- The generation of harmonic beats through the application of very small yet still distinguishable intervals.
- The creation of microtones through aleatoric means where microtones occur in a random and/or unpredictable way, for instance, by using piano preparation, certain percussion sounds, glissandi, or *ad libitum* detuning of strings etc.

The above list, although not complete, covers some of the main development trajectories of microtonal pitch organization in the 20th Century.

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[41] Ernstalbrecht Stiebler, ´Mikrotonalität – eine zweite Avantgarde?`, *Mikrotonale Tonwelten*, ed. Heinz-Klaus Metzger and Rainer Riehn (München, 2003), 213-15

[42] Georg Friedrich Haas, ´Mikrotonalitäten`, *Mikrotonale Tonwelten*, ed. Heinz-Klaus Metzger and Rainer Riehn (München, 2003), 59

Further methods include:

- The use of other known tuning systems, such as Pythagorean or meantone temperament, or the application of any other (also: non-European) tone-systems.
- The establishment of pitch hierarchies based on the re-syntheses of overtone configurations found in (instrumental) spectra.
- The application of microtones as structural devices.
- The use of unspecified microtones, predominantly as colouristic devices.

The beginnings of 20th Century microtonality were clearly dominated by the development of pitch systems seeking to extend the pitch material within equal temperament. These attempts can be interpreted as a continuation of a development in which pitch progressions became increasingly chromatic and key relations were treated with greater flexibility. At a time when composers pushed the boundaries of their pitch systems ever closer to an (at least theoretical) equality of all common intervals, it was a logical conclusion to consider applying intervals smaller than a semitone to the newly discovered chromatic pitch systems in which notes increasingly related only to one another. Microtones could therefore be implemented both in tonal and atonal contexts – in each case they both extended and refined the possibilities of a chromatic pitch language.

The earliest practice-based research into microtonality in Western culture had been undertaken in the late 19th Century[43]; it focused exclusively on microtonality within equal temperament. There were two different representatives of this development who, unbeknownst to each other for a long period of time, worked simultaneously on very similar issues: Julián Carrillo in Mexico, and a group of composers and theorists mentored by Ferrucio Busoni in Berlin.

2 Julián Carrillo and the *Sonido trece*

Carrillo (1875-1965) began his research into the possibilities of microtonal extension of the equal temperament twelve-tone scale by attempting to define the smallest distinguishable interval. In 1895, he conducted experiments on his violin and used a pocket knife to gauge the smallest possible intervals within an octave. He concluded that a sixteenth-tone was the smallest distinguishable interval.[44] Based on this assumption Carrillo developed his *Sonido trece* (i.e. the "thirteenth tone", a term that, however, actually refers to the discovery of the

[43] I am referring to the research of microtonality that is concerned with the practical application of microtones in compositions. A fair amount of research had been done in the field of music theory prior to the 19th Century, mainly with regard to different temperaments.
[44] Hans Rudolf Zeller, ´Komposition und Instrumentarium`, *Mikrotonale Tonwelten*, ed. Heinz-Klaus Metzger and Rainer Riehn (München, 2003), 25

sixteenth-tone), which contains a collection of various micro-tone-systems. These tone-systems include all intervallic gradations from the whole-tone to the sixteenth-tone, the whole-tone thereby serving as the reference interval for all microtonal sub-divisions. Carrillo consistently pursued an empirical approach in order to develop his tone-systems: by 1917 a sixteenth-tone harp with the range of one octave had been built soon followed by quarter-tone strings and woodwinds as well as sixteenth-tone brass instruments.[45] He first utilized excerpts from his *Sonido trece* in his piece *Preludio a Colón* in 1922, for which he used the compatible quarter-, eighth-, and sixteenth-tone systems. From the mid-1920s onwards Carrillo´s music received growing attention partially due to the fact that the conductor Leopold Stokowski (1882-1977) had developed a strong interest in his music. Stokowski stated that

> ´With the 16ths of tone, you are beginning a new musical era, and I want to be of service to this cause. [. . .] The great difficulty of this music resides in the fact that if you do not direct it, no one will be able to grasp the subtleties which the music contains […].`[46]

In 1927 Stokowski performed Carrillo´s *Concertino* with the Philadelphia Orchestra, and by 1930 Carrillo and his students had founded the first orchestra specifically suited to performances of microtonal music based on his *Sonido trece*. In 1931, Stokowski and Carrillo toured Mexico with this orchestra whose members were performing on specifically built microtonal instruments.[47] By 1940 Carrillo had his fifteen *Pianos metamorfoseadores* patented which were eventually built between 1949 and 1958.[48] These "transformed" instruments finally enabled him to practically represent all sub-systems of the *Sonido trece*: Piano No.1 was tuned in whole-tones, No.2 in third-tones, No.3 in quarter-tones…and No.15 in sixteenth-tones (the overall pitch range of the latter was limited to one octave). These instruments were presented to the public at the 1958 World Exhibition in Brussels; here Carrillo´s "super-system" (the *Sonido trece*) had found its practical counterpart in form of a "super-instrument".

Carrillo was highly pragmatic about the use of his microtonal systems: those systems containing very small intervals were used mainly for pieces written for his specifically built microtonal instruments whereas on occasion he would merge microtone and semitone systems in order to facilitate performances on conventional instruments. In addition to these technical considerations he also had what could be called a "pedagogical concern" for his performers and audiences alike. Carrillo was aware that an all too sudden radical departure from traditional chromaticism in favour of a "hyper-microtonalism" could alienate him from

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[45] Gerald R. Benjamin, ´ Julian Carrillo and "Sonido Trece" ("Dedicated to the Memory of Nabor Carrillo")`, *Anuario*, Vol. 3 (1967), 47

[46] Benjamin, op. cit., 46

[47] Benjamin, op. cit., 47

[48] H.R. Zeller, ´Komposition und Instrumentarium`, *Mikrotonale Tonwelten*, ed. Heinz-Klaus Metzger and Rainer Riehn (München, 2003), 25-26

both his performers and audiences.[49] He therefore occasionally opted for what Gerald R. Benjamin described as a ´free interchange (both in juxtaposition and superimposition) of old and new sounds`.[50] This could refer to the waiving of employing microtones in an atonal context but also to the use of microtones in a tonal context. An interesting combination of both concepts can be found in his *Concertino* written for the Philadelphia Orchestra in 1927: there are no microtones in the orchestral parts whereas the soloists (who are playing on specifically built microtonal instruments) perform quarter-tones (violin, guitar, cello), eighth-tones (octavina) and sixteenth-tones (harp).

Carrillo composed altogether 44 works in *Sonido trece* until his death in 1965; these include orchestral, choral, chamber and solo works. A study of his work catalogue shows that the vast majority of his microtonal works is based on the quarter-tone system which is occasionally extended to the compatible eighth- and sixteenth-tone systems. Exceptions can be found in pieces like *Estudio en 3os. de tono* for guitar (third-tones), *Preludios para piano metamorfoseador en 5os. de tono* for his fifth-tone piano, or his *Concertino para piano metamorfoseador de tercios de tono con acompafiamiento de orquesta sinf6nica en semitones*, a Concertino for third-tone piano and non-microtonal orchestra.

While those of his pieces that juxtapose microtonal and non-microtonal systems explore the differences between old and new sounds and thus create new contexts for the former (Benjamin points out that semitones become tones ´per se again` due to their de-contextualization)[51], those pieces written in the sixteenth-tone system display other characteristics: here gradually descending and ascending microtone glissandi replace distinctive tone steps.

An issue of importance to every microtonal composer is the aspect of how to notate micro-intervals. Carrillo decided to strike a new path by abandoning traditional notation. Instead of using the conventional system with five lines, note-heads and accidentals, he chose to translate his pitches into absolute and relative numbers that can be displaced or multiplied depending on the type of tone-system used for a piece.[52]

When Carrillo showcased his fifteen pianos in Brussels in 1958, Edgard Varèse was also present, demonstrating his *Poème électronique*.[53] The encounter of these two different worlds, the elaborate construction of an acoustic "super-instrument" on the one hand and the

[49] G.R. Benjamin, ´ Julian Carrillo and "Sonido Trece" ("Dedicated to the Memory of Nabor Carrillo")`, *Anuario*, Vol. 3 (1967), 44
[50] Benjamin, op. cit., 46
[51] Benjamin, op. cit., 46
[52] For a detailed exploration of Carrillo´s notational methods see: G.R. Benjamin, ´ Julian Carrillo and "Sonido Trece" ("Dedicated to the Memory of Nabor Carrillo")`, *Anuario*, Vol. 3 (1967), 50-58
[53] H.R. Zeller, ´Ferrucio Busoni und die musikalische Avantgarde um 1920`, *Mikrotonale Tonwelten*, ed. Heinz-Klaus Metzger and Rainer Riehn (München, 2003), 14

pioneering exploration of a new rising medium on the other, gave a first indication of the anachronism of Carrillo´s methods. Even though the Berlin based circle around Alois Hába was intrigued by Carrillo´s achievements[54], it soon became clear that the future of complex microtonal music lay in the field of electro-acoustic music. In Europe Carrillo´s music quickly sank into oblivion while in Mexico he is as of today still considered as one of the greatest composers in Mexican history.

3 Ferrucio Busoni

In 1907, twelve years after Carrillo had begun working on his *Sonido trece*, Italian composer Ferrucio Busoni (1866-1924) published his *Sketch of a New Esthetic of Music*. One of the central topics discussed in that *Sketch* is Busoni´s critique of the major/minor-tonal system:

> ´What we now call our Tonal System is nothing more than a set of "signs"; an ingenious device to grasp somewhat of that eternal harmony; a meager pocket-edition of that encyclopedic work; artificial light instead of the sun.`[55]

The development of a consummate tone-system, one capable of embodying that ´eternal harmony`, was an essential part of Busoni´s considerations. From his point of view, some of the gravest shortcomings of the major/minor-tonal system were its limitations regarding the number of different intervals and scales:

> ´And within this duodecimal octave we have marked out a series of fixed intervals, seven in number, and founded thereon our entire art of music. What do I say – *one series*? Two such series, one for each leg: The Major and Minor scales.[…] How violently contracted a system arose from this initial confusion, may be read in the law-books; we will not repeat it here.`[56]

He specified his critique by opining that the tonal system, despite of its 24 series (twelve Major, twelve Minor) actually only contains two qualitative series, Major and Minor, ´the rest are merely transpositions.`[57] This critique of the tonal system initially led him to the development of a set of altogether 113 different scales, which resulted from his experimenting with musical scale synthesis.[58] All these scales are variations on seven-tone scales; however, unlike the traditional major and minor scales the Busoni scales exhibit various forms of different interval progressions. Busoni created alternative intervallic contexts by applying third-degree enharmonic pitch description (´E flat`, ´D sharp`, ´F

[54] G.R. Benjamin, ´ Julian Carrillo and "Sonido Trece" ("Dedicated to the Memory of Nabor Carrillo")`, *Anuario*, Vol. 3 (1967), 49
[55] Ferrucio Busoni, ´Sketch of a New Esthetic of Music`, *Three Classics in the Aesthetic of Music* (New York, 1962), 89
[56] Busoni, op. cit., 90
[57] Busoni, op. cit., 90
[58] Robert M. Mason, ´Enumeration of Synthetic Musical Scales by Matrix Algebra`, *Journal of Music Theory*, Vol. 14, No. 1 (Spring, 1970), 93

double-flat`, and ´C triple-sharp` are all seen as different pitches depending on their scalar context).[59]

In addition to developing this set of scales Busoni also suggested the application of microtonal interval partitioning. Unlike Carrillo, who, despite the theoretical comprehensiveness of his *Sonido trece* favoured a quarter-tone based system, Busoni proposed the use of third- and sixth-tone systems, identifying the ´tripartite tone` as the next step toward ´eternal harmony`.[60] He was particularly interested in the properties of the whole-tone scale, and saw third-tones as a means to refine it.[61] The sub-division of each whole-tone into three equidistant steps indeed both emphasizes and refines the whole-tone scale since intervals such as semitones, minor thirds and perfect fifths are absent from the third-tone scale. Soon after developing his third-tone system Busoni introduced a sixth-tone system which was derived from two series of third-tones a semitone apart from each other. Just as Carrillo, Busoni was confronted with the issue of having to develop a notational method for the microtone steps. He chose a less radical approach than Carrillo, and suggested replacing the traditional five lines per staff with six lines whereby whole-tones are notated on the lines and semi-tones in the spaces between the lines while the commonly known sharps and flats indicate notes raised or lowered by a third-tone respectively.[62]

Even though Busoni had developed substantial theories for a third-tone system he never actually utilized these theories in any of his own compositions; one reason for this hesitant attitude can be found in the lack of microtonal instruments he could experiment with (according to his student Alois Hába he was waiting for a sixth-tone harmonium to be built for him[63]; unfortunately Busoni died before the instrument could be built). He nevertheless set the theoretical ground for a group of young microtonal composers who he mentored until his death.

4 Alois Hába

The central figure of this group was the Czech composer Alois Hába (1893-1973). He had initially studied with Franz Schreker in Vienna and decided to follow him to Berlin in 1920. There he joined a group whose members dealt with the subject of microtonality (other members included Russian composer Ivan Wyschnegradsky [1893-1979], German composer

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[59] For a list of all Busoni-scales see: R. M. Mason, ´Enumeration of Synthetic Musical Scales by Matrix Algebra`, *Journal of Music Theory*, Vol. 14, No. 1 (Spring, 1970), 115-123

[60] F. Busoni, ´Sketch of a New Esthetic of Music`, *Three Classics in the Aesthetic of Music* (New York, 1962), 93

[61] Busoni, op. cit., 93

[62] Busoni, op. cit., 94

[63] Alois Hába, *Neue Harmonielehre* (Leipzig, 1927), XIV

Willi Möllendorff [1872-1934] and the instrument inventor Jörg Mager [1880-1939]). Hába had written his first major quarter-tone composition in Vienna in 1920, i.e. his *String Quartet No.2 op.7* in which the quarter-tones are used as part of a highly chromatic late-romantic tonal pitch language (the piece was premiered in Berlin in 1922). Hába continued to write quarter-tone music (though not exclusively) throughout his life – as in Carrillo´s case the vast majority of his microtonal works were limited to the use of quarter-tones (however, without the extensions to the eighth- and sixteenth-tone systems). His main output of microtonal music can be found among his sixteen string quartets, but there are also works for specifically built microtonal instruments such as his *Suites* and *Fantasies* for quarter-tone piano (a quarter-tone grand piano based on Hába´s and Wyschnegradsky´s concepts was built by both Grotrian-Steinweg [two manuals] and August Förster [three manuals] and presented to the public in 1924)[64] or his *Suites* for quarter-tone guitar, clarinet, trumpet or trombone. In addition, he also composed quarter-tone pieces for voices including his opera *Matka* op.25 (1927-29) or the *Five Mixed Choruses* op.44 (1932). Aside from his preference for quarter-tone based systems he also implemented Busoni´s sixth-tone concept: in 1923 he composed his *String Quartet No.5 op.15* based on a sixth-tone system and once Schiedmayer had provided the first sixth-tone harmonium in 1926 (followed by an improved version built by Förster in 1927)[65] Hába wrote his *Six Pieces for Sixth-Tone Harmonium op.37* in 1928. In addition to the quarter- and sixth-tone systems Hába also once utilized the fifth-tone system (*String Quartet No.16 op.98* [1967]) and at least theoretically explored the twelfth-tone system in his *Harmonielehre*, however, without ever implementing it in any of his works.[66] With regard to the notation of microtones Hába chose yet another approach than Carrillo and Busoni: instead of changing the commonly accepted notation standards he invented sets of new accidentals for quarter-, sixth- and twelfth-tone systems (there are eleven different accidentals for the twelfth-tones within a whole-tone).[67] These accidentals – particularly those for the quarter-tone notation – became thereafter one of the standard notation devices for microtones but have in more recent days been replaced by the notation method of Richard Heinrich Stein (1882-1942) who had developed a theory of tonal quarter-tone harmony in 1906 and 1909 respectively.[68]

While Möllendorff´s compositional contributions remained negligible, Ivan Wyschnegradsky composed a substantial amount of works in the quarter-tone system (his

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[64] H.R. Zeller, ´Komposition und Instrumentarium`, *Mikrotonale Tonwelten*, ed. Heinz-Klaus Metzger and Rainer Riehn (München, 2003), 23
[65] H.R. Zeller, ´Ferrucio Busoni und die musikalische Avantgarde um 1920`, *Mikrotonale Tonwelten*, ed. Heinz-Klaus Metzger and Rainer Riehn (München, 2003), 18
[66] Zeller, op. cit., 17
[67] Erhard Karkoschka, *Das Schriftbild der Neuen Musik* (Celle, 1966), 2-3
[68] G.F. Haas, ´Mikrotonalitäten`, *Mikrotonale Tonwelten*, ed. Heinz-Klaus Metzger and Rainer Riehn (München, 2003), 60

first microtonal pieces were exclusively written for quarter-tone piano)[69]. Characteristic for his use of quarter-tones was their application to create a dense sound continuum resulting in a phenomenon described as “ultra-chromaticism”, doubtlessly inspired by the late works of Scriabin.

By the late 1920s the group around Hába had established one of the main aesthetic schools of its day (alongside dodecaphony, young classicality and “noise music”, only to name a few) – interestingly their music was not referred to as “microtonal music” but as “Vierteltonmusik” (quarter-tone music) instead.[70,71] On the one hand, this rather inadequate term not only omitted Busoni´s and Hába´s efforts in the realm of third- and sixth-tone music but also declared microtonal music of that time period to be generally synonymous to quarter-tone music. On the other hand, however, it curiously anticipated (and probably partially induced) a large amount of quarter-tone music written by numerous composers in the decades to follow. After the end of World War II the tempered quarter-tone rapidly became the most commonly used microtonal interval; however, since other parameters such as serial organization principles and the development of electro-acoustic music were clearly prioritized over microtonal pitch systems the term “Vierteltonmusik” was not associated with music by composers of the post-war avant-garde.

While Carrillo and the group around Hába developed their microtonal systems based on alternative tempered sub-divisions of intervals, a further development began to emerge in the USA, best exemplified by the work of Harry Partch.

5 Harry Partch

Partch was openly dismissive towards pitch languages based on equal temperament and the twelve-tone technique in particular, mainly due to the many intonational inaccuracies (compared to just intervals) that are inherent in those systems. In an undated memorandum in the University of Wisconsin Press Files Partch urged the Dean of the Graduate School

> ´That he have an open mind to arguments for Just Intonation. […]There is a two-thousand-year cleavage among theorists. On one side are those who believe in Equal Temperament, in compromising the capacity of the inner ear for the sake of expediency. […]On the other side are those who believe in forcing solutions in regard to instruments and comprehension to the satisfaction of the inner ear. I am definitely in the second group, and today we are very much in the minority.`[72]

69 <http://digitalmusics.dartmouth.edu/~franck/iw/catal.htm> [accessed 08 February 2010]

70 Lotte Kallenbach-Greller, ´Historische Grundlagen der Vierteltöne`, *Archiv für Musikwissenschaft,* 8. Jahrg., H. 4. (Sep., 1927), 473-485

71 A. Holde, ´Is There a Future for Quarter-Tone Music?`, *The Musical Quarterly*, Vol. 24, No. 4 (Oct., 1938), 528-533

72 Ronald V. Wiecki, ´Relieving "12-Tone Paralysis": Harry Partch in Madison, Wisconsin, 1944-1947`, *American Music*, Vol. 9, No. 1 (Spring, 1991), 53

It therefore comes as no surprise that Partch was highly critical of the approaches that Carrillo or Busoni/Hába respectively had chosen. In his textbook *Genesis of a Music* he points out that neither Carrillo´s (or, as a matter of fact, anybody else´s) tempered quarter-tone scales nor Busoni´s or Hába´s sixth-tone scales can be utilized as the basis for a pitch system ´without involving falsities so great as to destroy the assumptive ability of the ear. If a temperament is changed to favor one identity, two or three others will suffer; […]`[73]

Partch therefore devoted himself to the development of pitch systems based on Just Intonation (JI). In terms of its initial meaning, JI represents a theory of musical intervals and scales based on *small integer ratios*;[74] these intervals are perceived by the human ear as particularly consonant as they have shorter periods than those with larger integer ratios: for instance, the combined wave $\frac{3}{2}$ (the just fifth) repeats after six periods while the combined wave $\frac{47}{32}$ (another fifth that sounds 36 cents [a sixth-tone raised by three cents] sharp compared with the just fifth $\frac{3}{2}$) repeats after 1504 periods and will therefore be perceived by the human ear as clearly more dissonant. This outlook on consonance and dissonance is admittedly only one of many that have been developed over the past few centuries but it is of pivotal importance to the concept of JI.

The basic JI scale was published by Giuseppe Zarlino in 1558 and contains the following ratios: $\frac{1}{1}, \frac{9}{8}, \frac{5}{4}, \frac{4}{3}, \frac{3}{2}, \frac{5}{3}, \frac{15}{8}, \frac{2}{1}$. It is a 5-limit scale and all of its frequency ratios naturally occur in the overtone series. This scale introduces three different intervallic steps: (1) a semitone ($\frac{16}{15}$): for instance, between $\frac{5}{4}$ and $\frac{4}{3}$; (2) the "major tone", the whole-tone $\frac{9}{8}$: for instance between $\frac{1}{1}$ and $\frac{9}{8}$; (3) the "minor tone", the whole-tone $\frac{10}{9}$: for instance, between $\frac{9}{8}$ and $\frac{5}{4}$. The "major tone" sounds approximately an eighth-tone higher than the "minor tone"; this difference is called the *Syntonic Comma*.

One of Partch´s central aims was to extend this scale by applying further smaller just intervals in order to fill the gaps between the intervals mentioned above. He experimented with 29-, 37-, 39-, 41-, and 55-step systems before settling with his 43-step scale.[75] This scale, which he called "monophonic fabric", is a comprehensive symmetrical construct based on proportions from both overtone and undertone series. Partch extended Zarlino´s original 5-limit JI scale by adding frequency ratios with 7-, 9-, and 11-limits. This initially

[73] Harry Partch, *Genesis of a Music* (New York, 1979), 431
[74] Ratios describe the proportion of the frequencies of two pitches constituting an interval. For instance, an octave above A4=440Hz is A5=880Hz which is expressed through the ratio $\frac{2}{1}$.
[75] Bob Gilmore, ´Changing the Metaphor: Ratio Models of Musical Pitch in the Work of Harry Partch, Ben Johnston, and James Tenney`, *Perspectives of New Music*, Vol. 33, No. 1/2 (Winter - Summer, 1995), 462

led to a 29-step scale consisting of intervals with the smallest possible integer ratios within the given limits, i.e. a scale made of very consonant just intervals. These intervals were described by Partch as the ´Primary Ratios`.[76]

$$\mathbf{\frac{1}{1}} - \frac{12}{11} - \frac{11}{10} - \frac{10}{9} - \mathbf{\frac{9}{8}} - \frac{8}{7} - \frac{7}{6} - \frac{6}{5} - \frac{11}{9} - \mathbf{\frac{5}{4}} - \frac{14}{11} - \frac{9}{7} - \mathbf{\frac{4}{3}} - \frac{11}{8} - \frac{7}{5} -$$

$$\frac{10}{7} - \frac{16}{11} - \mathbf{\frac{3}{2}} - \frac{14}{9} - \frac{11}{7} - \frac{8}{5} - \frac{18}{11} - \mathbf{\frac{5}{3}} - \frac{12}{7} - \frac{7}{4} - \frac{16}{9} - \frac{9}{5} - \frac{20}{11} - \frac{11}{6} - \mathbf{\frac{2}{1}}$$ [77]

An examination of this scale shows Partch´s careful attempt to create a succession of simple consonant just intervals: it exemplifies the importance of *pure* intervals (defined by the absence of beats in the intervals based on small ratio integers) for his harmonic and melodic language. A further important feature of this scale is its inherent symmetry: the symmetrical axis is located between $\frac{7}{5}$ and $\frac{10}{7}$, and the second part of the scale features intervals *complementary* to those of the first part (e.g., $\frac{7}{5}$ and $\frac{10}{7}$ [$\frac{7}{5} \times \frac{10}{7} = \frac{70}{35} = \frac{2}{1}$] or $\frac{11}{8}$ and $\frac{16}{11}$ [$\frac{11}{8} \times \frac{16}{11} = \frac{176}{88} = \frac{2}{1}$] or the perfect fourth $\frac{4}{3}$ and the perfect fifth $\frac{3}{2}$ [$\frac{4}{3} \times \frac{3}{2} = \frac{12}{6} = \frac{2}{1}$] etc). The second part of the scale thus mirrors the first one with regard to its interval properties. This characteristic can be linked directly to Partch´s concepts of "otonality" (a set of overtones of a pitch) and "utonality" (a set of undertones of a pitch) in which he claims that every pitch has a harmonic "double identity": one based on its overtones and the other based on its undertones. The undertone series basically is a symmetrical mirror-image of the overtone series, meaning that the undertones of a fundamental are complementary to its overtones, a phenomenon apparent in Partch´s 29-step scale.

While this scale fulfills the requirements of symmetrical construction and usage of comparatively pure just intervals it, however, also displays a certain degree of unevenness regarding its interval progressions. For example, both the very first and very last intervallic steps of the scale ($\frac{1}{1}$ to $\frac{12}{11}$ and $\frac{11}{6}$ to $\frac{2}{1}$ respectively) amount to 151 cents (a three-quarter tone) whereas the adjacent intervals are often significantly smaller (e.g., the $\frac{11}{10}$ raises the $\frac{12}{11}$ by 12 cents, i.e. by merely a sixteenth-tone).

Partch addressed this issue by adding fourteen so-called ´secondary pitches` and thus filled the gaps between the larger intervals. This additional refinement eventually led to his 43-step scale:

[76] H. Partch, *Genesis of a Music* (New York, 1979), 157
[77] Johannes Fritsch, ´Allgemeine Harmonik, Tonsysteme, Mikrotonalität – ein geschichtlicher Überblick`, *Orientierungen – Wege im Pluralismus der Gegenwartsmusik*, ed. Jörn Peter Hiekel (Schott, 2007), 120

$$\mathbf{\frac{1}{1}} - \frac{81}{80} - \frac{33}{32} - \frac{21}{20} - \frac{16}{15} - \frac{12}{11} - \frac{11}{10} - \frac{10}{9} - \mathbf{\frac{9}{8}} - \frac{8}{7} - \frac{7}{6} - \frac{32}{27} - \frac{6}{5} - \frac{11}{9} - \mathbf{\frac{5}{4}} - \frac{14}{11} - \frac{9}{7} - \frac{21}{16} - \mathbf{\frac{4}{3}} - \frac{27}{20} - \frac{11}{8} - \frac{7}{5} -$$

$$\frac{10}{7} - \frac{16}{11} - \frac{40}{27} - \mathbf{\frac{3}{2}} - \frac{32}{21} - \frac{14}{9} - \frac{11}{7} - \frac{8}{5} - \frac{18}{11} - \mathbf{\frac{5}{3}} - \frac{27}{16} - \frac{12}{7} - \frac{7}{4} - \frac{16}{9} - \frac{9}{5} - \frac{20}{11} - \frac{11}{6} - \mathbf{\frac{15}{8}} - \frac{40}{21} - \frac{64}{33} - \frac{160}{81} - \mathbf{\frac{2}{1}};$$ [78]

The three-quarter-tone steps both at the beginning and end of the scale have been further subdivided; in addition, further interval refinements were included (see ratios in italic).[79]
The initial symmetry of the scale is maintained including the phenomenon of complementary interval relations.
A consequence of this additional refinement procedure was the partial loss of intervallic purity brought about by the inclusion of larger integer ratios. This led to a number of intervals displaying a comparatively greater degree of dissonance. Partch addressed this issue by determining a hierarchy of interval types within his monophonic fabric. He introduced four classes of intervals, graphically represented in his famous ´One-Footed-Bride: A Graph of Comparative Consonance`:[80]

- *Intervals of Power*: 3-limit ratios such as $\frac{2}{1}$, $\frac{3}{2}$, and $\frac{4}{3}$; these intervals are commonly described as "perfect intervals" (octave, fifth, fourth)
- *Intervals of Suspense*: the ratios between $\frac{4}{3}$ and $\frac{3}{2}$, in other words, the "tritone intervals"[81]
- *Emotional Intervals*: the ratios between $\frac{21}{16}$ and $\frac{7}{6}$ as well as their complements between $\frac{32}{21}$ and $\frac{12}{7}$; this group of intervals contains various thirds and sixths
- *Intervals of Approach*: the ratios between $\frac{8}{7}$ and $\frac{1}{1}$ and their complements between $\frac{7}{4}$ and $\frac{2}{1}$; this set consists of semitones, whole-tones, minor and major sevenths

This subjective evaluation of interval types contained in the monophonic fabric corresponds with previous interpretations of the function and meaning of intervals. The principle differences and thus the novelty of this approach can be found in the exclusive use of just intervals and the microtonal refinements of the interval steps within the octave that come with it. This system contains intervals that allow for the use of various "traditional" scales including Pythagoreian seven-tone scales, most of the Ptolemy scales, and even some equitempered scales. Most importantly though it generates a rather balanced set of just

[78] H. Partch, *Genesis of a Music* (New York, 1979), 157
[79] Interestingly, Partch reintroduced the just major seventh $\frac{15}{8}$ from the original JI scale into his 43-step scale; this ratio had previously been omitted from the 29-tone scale. All intervals from Zarlano´s JI scale are thus present in Partch´s 43-step scale.
[80] Partch, op. cit., 155
[81] Note that Partch´s system does not contain the otherwise commonly used just tritone $\frac{45}{32}$.

intervals including all the basic intervals as well as some of their variations with varying degrees of intervallic complexity.

Similar to Carrillo and Hába, Partch was aware that his microtonal pitch system depended upon precise intonation if its novel degree of pitch differentiation was to be effectively realized. The former two composers utilized at least some specific microtonal instruments built for them, even though both continued to write non-microtonal music for traditional instruments. Partch, in contrast rigorously followed an empirical method by building (or having built) instruments specifically suited to the monophonic fabric. There is, in fact, an inseparable connection between the tone-system, its graphic representation, the construction of instruments, the notation of the music, and its performance. For example, the graphic model of a specific structure of the fabric (illustrating the otonalities and utonalities of pitches) as seen in Partch´s *tonality diamond*[82] is mirrored in the layout of his *Diamond Marimba* whose bars are arranged according to the graphic model of the fabric.[83] As a consequence, the tone-system is mirrored in the playing method since chord progressions follow the practicalities of the instruments, which are linked to the tone-system. The pitches are notated in form of tablatures which reflect upon the graphic model of the fabric and thus upon the fabric itself. Due to the interactive cohesiveness of all these parameters the instrumental writing becomes highly idiomatic; one might claim that in Partch´s case the tone-system and the instruments are of equal mutual importance to the actual outcome, the compositions.

Partch vehemently defended his approach, and throughout his life continued to criticize the established music world of his time and the contemporary developments of Western-art music in particular. Referring to what he thought was a stagnation in art music, he declared in his essay “Show Horses in the Concert Ring” dated from 1946 that

> ´A period of comparative anarchy, with each composer employing his own instrument or instruments, his own scale, his own forms, is very necessary for a way out of this malaise.`[84]

The core of his critique was directed at the unwillingness of the “musical establishment” to reconsider and rediscover the natural properties of human hearing, in other words the lack of interest in music utilizing pitch material based on just intervals. Partch accused the “establishment” and its tendency to favour traditional over experimental music of artistic stasis (´The only real vitality in this entire picture is exuded by the men who are out to make money in the deal`[85]) while in the meantime his music caused plenty of controversy – for

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[82] H. Partch, *Genesis of a Music* (New York, 1979), 159
[83] Partch, op. cit., 259 ff.
[84] R. V. Wiecki, ´Relieving "12-Tone Paralysis": Harry Partch in Madison, Wisconsin, 1944-1947`, *American Music*, Vol. 9, No. 1 (Spring, 1991), 49
[85] Wiecki, op. cit., 49

example, Partch reported to his fellow composer Otto Luening about a performance in 1945 where

> ´The band leader [R. F Dvorak] declared that my talents should be spent in the local ammunition works and that my instruments should be scrapped for the war effort.`[86]

Despite his somewhat eccentric and esoteric ways (both personally and musically) and the often antagonistic and confrontational relationship between him and great parts of the public and the musical establishment, Partch did eventually gain significant influence on other composers as well as music theorists. His theories on tone-systems and their practical application were groundbreaking and continue to influence composers, instrument makers and theorists alike to this day.

6 The Post-War Avant-garde

After World War II, when the European New Music scene began to reorganize itself, the focus was not initially directed towards the development of microtonal pitch systems. On the contrary, the main interest of the post-war avant-garde was concentrated on serialization of musical parameters and the exploration of the new possibilities that the electro-acoustic medium had to offer. The main representatives of the European avant-garde movement were nonetheless aware of the existence of microtonal concepts developed by the previous generation of composers. The equitempered quarter-tone became the most favoured microtonal interval, due on the one hand to the comparatively simple procedures that are required in order to perform them. Using quarter-tones meant on the other hand that ET could be maintained as a tone-systematic basis – an essential premise considering the importance the equitempered twelve-tone system held for the serialists. Furthermore, the singular subdivision of the semitone is (from a mathematical perspective) the most simple and logical extension of interval types within the dodecaphonic system: this way microtonality could be treated as a serial parameter without requiring any tone-systematic changes which would have been deemed aesthetically undesirable. Finally, quarter-tones are also highly characteristic intervals and (due to their relatively large size) easily distinguishable by the human ear.

Pierre Boulez (b.1925) used quarter-tones in the second version of his piece *Le Visage nuptial* for soprano, alto, female chorus and orchestra, premiered in 1957. He, however, withdrew the piece after the performance and chose to dispense with microtones from then onwards.[87] Iannis Xenakis (1922-2001) likewise used quarter-tones but also commonly

[86] Wiecki, op. cit., 47
[87] H.R. Zeller, ´Mikrointervalle in der Musik des 20. Jahrhunderts`, *Mikrotonale Tonwelten*, ed. Heinz-Klaus Metzger and Rainer Riehn (München, 2003), 56

generated indeterminate microtones through the frequent use of glissando gestures. A further example for the use of indeterminate microtones at that time is John Cage´s (1912-1992) output for prepared piano (e.g., the *Sonatas and Interludes*): the preparation of the instrument produces (at least to some extent) unpredictable microtones. Unlike Partch, Cage thereby chose a non-systematic escape from equal temperament.[88] Karlheinz Stockhausen (1928-2007) developed an alternative equitempered system for his electronic piece STUDIE II (1954) in which all pitches are based on the frequency proportion $\sqrt[25]{5}$, meaning that the interval $\frac{5}{1}$ (two octaves plus a just major third) is subdivided into 25 equidistant steps (a slightly raised semitone).[89] Luigi Nono (1924-1990) started using microtones relatively late in his life. He applied quarter-tones for the first time in his string quartet *Fragmente – Stille, An Diotima* (1980); later he even used eighth- and sixteenth-tones in his orchestral piece *A Carlo Scarpa, architetto, ai suoi infiniti possibili* (1984). György Ligeti (1923-2006) also initially employed quarter-tones as his microtonal reference interval (for instance, in the explanatory notes to his second string quartet [1968] he instructs the performers to produce indeterminate microtones either smaller than or not exceeding the size of a quarter-tone)[90]. In some of his later works, he also applied microtones based on the use of different temperaments (e.g., meantone temperament in his *Passacaglia ungherese* [1978] or just intonation in his *Violin Concerto* [1990-92]).[91]

7 *Musique concrète* and *Elektronische Musik*

As mentioned above, there was a second developmental thread of great relevance to the post-war avant-garde: the emergence of electro-acoustic music. Electronic instruments were predestinated for flexible and precise intonation of microtones as they could be built specifically to meet such criteria. Jörg Mager, member of Hába´s "microtonal group", recognized this potential and had his first *Sphärophon* (an electronic instrument that could produce any microtonal interval – Mager thus described it as a ´omnitonium`)[92] built by the company Lorenz in 1921 with the intention to use it for an effective realization of his quarter-tone system.[93] Even though Mager was encouraged to refine and improve his instrument and also continued to build further electronic instruments such as his "Partiturophon" in 1931, his concepts did not have a lasting effect as the development of

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[88] Zeller, op. cit., 56

[89] J. Fritsch, ´Allgemeine Harmonik, Tonsysteme, Mikrotonalität – ein geschichtlicher Überblick`, *Orientierungen – Wege im Pluralismus der Gegenwartsmusik*, ed. Jörn Peter Hiekel (Schott, 2007), 118

[90] György Ligeti, *String Quartet No.2*, Schott ED 6639, 1971

[91] György Ligeti, Manfred Stahnke, ´Ein Gespräch`, *Mikrotonale Tonwelten*, ed. Heinz-Klaus Metzger and Rainer Riehn (München, 2003), 76-78

[92] André Ruschkowski, *Elektronische Klänge und musikalische Entdeckungen* (Stuttgart, 1998), 40

[93] Ruschkowski, op. cit., 38

electro-acoustic music went into different directions thereafter.[94] These new directions were characterized on the one hand by the *musique concrète*, founded by Pierre Schaeffer (1910-1995), which first attracted greater attention in 1948 after a Paris broadcast.[95] On the other hand there was the Cologne based movement of *Elektronische Musik*, initially set up by Herbert Eimert (1897-1972), which similar to the *musique concrète*, was "officially launched" in 1953 at a broadcast by the Northwest-German-Broadcasting Corporation.[96] The aesthetic of *musique concrète* was based on the idea of transforming sound objects (often noises) recorded from the real (concrete) world into musical structures through processes of editing; the intention was to start out with concrete material followed by its transformation into a (poetic) abstract state. The parameter pitch had no significant role with regard to tone-systematic considerations for Schaeffer and his colleague Pierre Henry (b.1927).

The aesthetic starting-point for the *Elektronische Musik* movement was to use electro-acoustic devices in order to allow timbre to become a serial parameter.[97] Eimert and Stockhausen thereby addressed the difficulty or even impossibility of exercising serial control over timbre by means of traditional acoustic instruments. This approach enabled the composers to actually *compose* timbre.[98] Of major interest were also the developments of both aleatoric and spatialization concepts, whereas the electronic realization of microtonal pitch systems was not considered a priority. In 1973 Stockhausen emphasized the importance of the role of spatialization as a new unconsumed parameter, especially since

> ´pitches are for the time-being still paralyzed. Harmony and melody merely function in a relative way, they are neutral due to the breakup and the complete phase-out of the tonal system.`[99]

It was eventually up to the composers of the French Spectral School to utilize the potential of electro-acoustic devices with regards to the analysis and realization of another unconsumed parameter, microtones.

By the 1960s microtones had become generally available as compositional tools and were no longer exclusively used by "specialist" composers such as Carrillo, Hába or Partch. The quarter-tone interval in particular had been gradually established as a standard interval and slowly became an integrated parameter in the music of some of the leading serial composers.

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[94] Ruschkowski, op. cit.,45
[95] Ruschkowski, op. cit.,209
[96] Ruschkowski, op. cit.,236
[97] Ruschkowski, op. cit.,232
[98] Karlheinz Stockhausen, ´Arbeitsbericht 1953. Die Entstehung der Elektronischen Musik`, *Texte, Band 1* (Köln, 1963), 42
[99] ´[...] die Tonhöhen vorläufig noch völlig lahmgelegt sind. Harmonik und Melodik funktionieren nur noch relativ, sind neutral durch das Zerbrechen bzw. das völlige Auslaufen des tonalen Systems.` (translated by the author) K. Stockhausen, ´Vier Kriterien der Elektronischen Musik (1973)`, *Texte, Band 4* (Köln, 1978), 383

8 New Complexity

This development continued with the emergence of a new aesthetic, the so-called *New Complexity* movement, which grew out of the serialist school. Its most eminent representative, Brian Ferneyhough (b.1943) frequently incorporates equitempered microtones (mainly quarter-tones) in his works. The quarter-tones in Ferneyhough´s music usually represent a refinement of the parameter pitch analogous to the levels of differentiation he applies to other musical parameters. This way they contribute to a global enhancement of detail within an overall dense complexity. As a result of this, the microtones are not used as specific (and thus precisely intonated) intervals but rather as an abstract momentum of differentiation. Furthermore, quarter-tones are used as ornaments, typically as part of microtonal trills or microtones circling around a centre pitch. Ferneyhough also applied microtones in what he called a "tempered" way, i.e. in a linear structural way. This method enhances and strengthens the communication and perception of certain structural units. An example for this can be found in his piece *Superscriptio* for solo piccolo (the first piece of his cycle *Carceri d´Invenzione*): suddenly, for the first time in the piece, quarter-tones are included in the pitch material which creates a noticeable effect of contrast (bars 139ff.).[100]

A similar application of quarter-tones can also occasionally be found in the works of "New Complexity" composer Michael Finnissy (b. 1946). In his piece *Câtana* for nine musicians (1984) the quarter-tones are used only in very specific sections of the piece.[101] Despite this structural use of the microtones they are also part of two very specific and clearly recognizable motivic elements: "hyper-chromatic" fast melodic gestures on the one hand and sustained chords approached by microtonal portamenti on the other. An additional example for Finnissy´s structural use of microtones is the procedure of globally halving the intervals of his pitch collection in the first piece of his *Obrecht Motetten* (1988-1992) which leads to the application of quarter-tones.[102] Not only does this process communicate a dynamic structural change but at the same time the quarter-tones (together with the other halved intervals) dramatically alienate the musical material.

It should be emphasized that the major European composers of the post-war avant-garde predominantly treated micro- (quarter-) tones either as abstract interval diminutions within (serial) equitempered atonality concepts (e.g., center-tone ornamentation, glissandi and portamenti, microtone clusters etc) or as similarly abstract structural devices – and rarely ever as *quality* intervals that were part of any *hierarchical* tone-systems.[103]

[100] Cordula Pätzold, ´Organisationsstrukturen in *Carceri d´Invenzione*`, *Brian Ferneyhough*, Musik-Konzepte 140, ed. Ulrich Tadday (München, IV/2008), 76
[101] Michael Finnissy, *Câtana*, United Music Publishers, 1985
[102] Ian Pace, ´The Panorama of Michael Finnissy (I)`, *Tempo*, New Series, No. 196 (04/1996), 34
[103] There are obviously exceptions such as the previously mentioned STUDIE II by Stockhausen.

9 Ben Johnston

It was American composer Ben Johnston (b.1926) who, as a successor to Harry Partch (with whom he had briefly studied in the early 1950s) undertook the task of building such hierarchical tone-systems. He attempted to reconcile Partch´s just intonation concepts with elements of European New Music;[104] his main European influence, however, was not the aesthetic of the Second Viennese School but much rather that of Claude Debussy:

> ´Schoenberg is an example of a radical thinker motivated strongly by a claustrophobic sense of nearly exhausted resources. Debussy, in sharp contrast, seems motivated by an expansion of harmonic resources and a greatly widened horizon.`[105]

Like his teacher Partch, he also expressed a negative attitude towards equal temperament and dodecaphony:

> ´Merely to multiply the number of available pitches, as with quarter-tones or any other system of temperament with more than twelve notes per octave, complicates the problem of harmonic organization without helping to solve it. Rather than to enlarge the pitch vocabulary by such artificial means, it is more desirable to expand the order we already perceive in it by means which we already understand in practice. `[106]

Influenced by his studies with Partch, Johnston began to write music in "extended just intonation". His commitment to proportional rather than linear organization of pitches illustrates the importance that melodic and harmonic pitch hierarchies held for his music.[107] Typically, the basic principle behind Johnston´s method of generating scales is to first define a centre pitch and then apply a network of relating intervals by adding certain proportions. The scope of the overall procedure is thereby regulated by the degree of the prime generative integers (the "limit") that is applied.[108] For example, the pitch material for his *Second String Quartet* is based on a complex 5-limit scale, which contains 53 pitches per octave. $\frac{5}{4}$ and $\frac{3}{2}$ proportions are applied above and below the center pitch $\frac{1}{1}$; this procedure is then repeated several times so that the pitch material begins to branch out. The material arranged as a scale then reads as follows:[109]

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[104] B. Gilmore, ´Changing the Metaphor: Ratio Models of Musical Pitch in the Work of Harry Partch, Ben Johnston, and James Tenney`, *Perspectives of New Music*, Vol. 33, No. 1/2 (Winter - Summer, 1995), 473

[105] Ben Johnston, ´A.S.U.C. Keynote Address,` in: *Maximum Clarity*, ed. Bob Gilmore (Urbana and Chicago, 2006), 156-157

[106] B. Johnston, ´Proportionality and Expanded Musical Pitch Relations`, *Perspectives of New Music,* Vol.5, No.1, (Autumn, 1966), 116

[107] B. Johnston, ´Scalar Order as a Compositional Resource`, *Perspectives of New Music*, Vol.2, No.2 (Spring-Summer, 1964), 61

[108] Note the similarity to Partch´s approach.

[109] Johnston, op. cit.,73

$$\mathbf{\frac{1}{1}} - \frac{81}{80} - \frac{128}{125} - \frac{25}{24} - \frac{135}{128} - \frac{16}{15} - \frac{27}{15} - \frac{1125}{1024} - \frac{10}{9} - \mathbf{\frac{9}{8}} - \frac{729}{640} - \frac{144}{125} - \frac{75}{64} - \frac{32}{27} - \frac{6}{5} - \frac{625}{512} - \frac{100}{81} \,|$$

$$\mathbf{\frac{5}{4}} - \frac{81}{64} - \frac{32}{25} - \frac{125}{96} - \frac{320}{243} - \mathbf{\frac{4}{3}} - \frac{27}{20} - \frac{512}{375} - \frac{25}{18} - \frac{45}{32} - \frac{64}{45} - \frac{36}{25} - \frac{375}{256} - \frac{40}{27} - \mathbf{\frac{3}{2}} - \frac{243}{160} - \frac{192}{125} - \frac{25}{16} - \frac{128}{81} - \frac{8}{5} - \frac{625}{384} - \frac{400}{243} \,|$$

$$\mathbf{\frac{5}{3}} - \frac{27}{16} - \frac{128}{75} - \frac{125}{72} - \frac{225}{128} - \frac{16}{9} - \frac{9}{5} - \frac{1875}{1024} - \frac{30}{27} - \mathbf{\frac{15}{8}} - \frac{243}{128} - \frac{48}{25} - \frac{125}{64} - \frac{160}{81} - \mathbf{\frac{2}{1}} \,||$$

Basically, this scale is an extended version of Partch´s monophonic fabric; it shares nineteen of its intervals and also contains Zarlano´s original JI scale. Two of Partch´s main criteria, however, are not met: on the one hand Johnston´s scale includes relatively large integer ratios (i.e. less pure and thus more dissonant intervals) while on the other hand the symmetry of the scale has become merely approximate at times (e.g., $\frac{1125}{1024} \text{ x } \frac{1875}{1024} = \frac{2109375}{1048576} = \frac{2.011657}{1} \neq \frac{2}{1}$).

Johnston used a more reduced set of pitches for his *Fourth String Quartet "Amazing Grace"*. A particularly interesting feature of this work is the fluctuation of complexity levels regarding the pitch material. The piece is a one movement "Theme and Variations" work based on the traditional tune "Amazing Grace". Johnston developed a 7-limit macro-scale consisting of 22 pitches which is missing two very common just intervals: the "major tone" ($\frac{9}{8}$) and the perfect fourth ($\frac{4}{3}$):

$$\mathbf{\frac{1}{1}} - \frac{28}{27} - \frac{16}{15} - \frac{10}{9} - \frac{8}{7} - \frac{7}{6} - \frac{6}{5} - \mathbf{\frac{5}{4}} - \frac{9}{7} - \frac{21}{16} - \frac{27}{20} - \frac{45}{32} - \frac{81}{56} - \mathbf{\frac{3}{2}} - \frac{14}{9} - \frac{8}{5} - \mathbf{\frac{5}{3}} - \frac{12}{7} - \frac{7}{4} - \frac{9}{5} - \mathbf{\frac{15}{8}} - \frac{27}{14} - \mathbf{\frac{2}{1}};$$ [110]

The scale is almost perfectly symmetrical around its axis $\frac{45}{32}$ and is based on small integer ratios (a feature that leads to remarkable acoustic results in this piece if the just intervals are intonated correctly). This macro-scale is, however, not constantly in use throughout the entire piece; instead, excerpts based on 3- and 5-limits are used in certain variations. The smallest excerpt is a pentatonic (five tones per octave) scale whereas the largest contains all 22 pitches. This way the number and size of prime generative integers fluctuates throughout the piece, while all scalar excerpts remain, however, part of one overall systematic approach. In addition, ratios are occasionally transformed (as part of the variation principle) following mathematical procedures such as subtraction (e.g., $\frac{28}{27}$ - 12 = $\frac{16}{15}$; etc) thus leading to different sub-scales that can be applied in order to create a denser fabric.

[110] B. Gilmore, ´Changing the Metaphor: Ratio Models of Musical Pitch in the Work of Harry Partch, Ben Johnston, and James Tenney`, *Perspectives of New Music*, Vol. 33, No. 1/2 (Winter - Summer, 1995), 482

The ratio scale does not only provide the pitch material for the piece, but it also generates the systems for metric and rhythmic proportions.[111] These procedures lead to a self-affinity of various musical parameters which are, at least to a certain degree, organized in a quasi fractal way.

Unlike Partch, Johnston neither built microtonal instruments suiting his theories nor did he write music for existing ones (with the exception of quarter-tone pianos). His choice to write for established traditional instrument combinations like, for instance, the string quartet, is a further example of his attempts to reconcile the old and the new (something Partch would have strongly objected to). This choice, however, also significantly complicates the issue of performance. No matter how naturally logical the melodic and harmonic contexts of just intervals may appear to the performer, their technical realization on a traditional instrument remains a major challenge which only few musicians are willing (and capable) to undertake. It therefore comes as no surprise that some of Johnston´s later works whose pitch systems are at times based on higher limit generative integers remain unperformed to this day.

10 James Tenney

Another composer who was strongly influenced by Partch and Johnston alike was American composer James Tenney (1934-2006). Even though he is mainly known for his achievements in the areas of electro-acoustic and computer music he was also very much concerned with the development of pitch systems based on ratio models. There are various parallels to the systematic approaches of his predecessors (e.g., describing pitches through ratios, application of prime generative integers to define the limits of a system, graphic representation of his pitch systems through lattice models), however, one significant difference lies in the fact that despite his application of generative methods for extended just intonation systems he frequently did not actually strictly adhere to them in some of his compositions.[112] That is to say that, unlike his predecessors, Tenney allowed for a tolerance range regarding the intonation of just intervals meaning that he did not reject the use of equal temperament in order to realize a different and more refined system.[113] For example, his piece *Changes: 64 studies* for six harps, composed in 1985, is based on the equitempered twelfth-tone system (72 equidistant steps per octave). As will be shown later in this work

[111] Randall Shinn, ´Ben Johnston´s Fourth String Quartet`, *Perspectives of New Music*, Vol. 15, No.2 (Spring – Summer, 1977), 152

[112] B. Gilmore, ´Changing the Metaphor: Ratio Models of Musical Pitch in the Work of Harry Partch, Ben Johnston, and James Tenney`, *Perspectives of New Music*, Vol. 33, No. 1/2 (Winter - Summer, 1995), 486

[113] The issue concerning the effectiveness of incorporating just intervals into equal temperament through their approximate representation remains a controversial subject for microtonal composers and theorists to this day. The problems that can occur with regards to notating a hierarchical system in a way where notes only relate to one another will be discussed later in this work.

this system has been used by various composers (e.g., Manfred Stahnke and Hans Zender) for the purpose of representing just intervals within equal temperament. Tenney emphasized the adequacy of this system for the representation of just intervals within the 11-limit by pointing out that the largest inaccuracy amounts to only three cents for the just major third $\frac{5}{4}$.[114] The practical realization of the system is achieved by the detuning of the instruments: the six harps are tuned a twelfth-tone (16.66 cents) apart from each other so that the ensemble can supply the 72 twelfth-tones per octave. Tenney then established different concepts to arrange the material; this includes its subdivision into pitch-classes that can function either as temporary roots, dominants or modes, as well as the application of stochastic principles.[115] In a further attempt to limit the sheer wealth of the material Tenney created a set of rules determining conditions of limitation regarding the use of certain intervals (e.g., the use of the raised fifth $\frac{25}{16}$ is only permitted in the context of a major third if that major third is expressed through the ratio $\frac{5}{4}$).[116] This example illustrates how carefully the value of each interval and its role for the musical discourse were considered by the composer. The guiding principle behind all these considerations was Tenney´s occupation with the issue of consonance and dissonance, an issue he attempted to resolve in a variety of ways. Characteristic for his oeuvre is therefore the multifariousness of his approaches: he constantly developed different methods for generating pitches (including, for instance, the use of the first 32 pitches of the overtone series for his piece *Saxony* for saxophone(s) and tape delay system [1978]); all these approaches can finally be summarized in his concept of "harmonic space".

11 *La musique spectrale*

When, in 1973, Hugues Dufourt, Gérard Grisey, Tristan Murail, Michaël Levinas and Roger Tessier teamed up to form the *Groupe L´Itinéraire*, the musical avant-garde had been dominated by serial music for about two decades. In response to this, the five composers introduced a new aesthetic (or maybe better: philosophy) which is known as "la musique spectrale", or the "French Spectral School".[117] [118]

The term "spectral" initially referred to various characteristics of a musical spectrum which can be defined as a collection of sine waves (partials). Each of these sine waves is characterized by its frequency, amplitude and phase. A Fast Fourier Transform (FFT) shows

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114 James Tenney, ´About Changes – Sixty-Four Studies for Six Harps`, *Perspectives of New Music*, Vol. 25, No. 1/2, 25th Anniversary Issue (Winter - Summer, 1987), 65

115 Tenney, op. cit.,71

116 Tenney, op. cit.,76

117 The term „spectrale" was derived from one of Dufour´s philosophical articles (see footnote 118)

118 Hugues Dufourt, ´Musique spectrale`, *Katalog zum Festival wien modern 2000: Elektronik – Raum – musique spectrale* (2000), 88

what constituents a spectrum is made of by breaking up a complex sound into its ´sinusoidal elements`.[119] In principle, these elements form the basis for generating “spectral” musical material. The term “spectral music”, however, remains problematic since not all members of the *Groupe L´Itinéraire* agreed that the term “spectral” sufficiently describes their aesthetic. Murail remarked that

> “They always call the music we make ´spectral`. Neither Gérard Grisey nor myself are responsible for that designation, which always struck us as insufficient.`[120]

Terms such as “spectral music” or “spectralist composer” have nonetheless become established notions, and in lack of a better terminology, I will continue to use them throughout this work.

The main intentions behind this aesthetic can be identified by the following essential points:

- Development of a new musical language based on scientific knowledge about acoustics and psychology of perception (*technological approach*)
- Skepticism about extrinsic construction models (*critique of serialism*)
- Emphasis on the central importance of sound/timbre as a shifting “living” organism (*naturalist approach*)
- Establishment of pitch hierarchies in which properties from the overtone series serve as a main point of reference

These aspects clearly define the aesthetic position of the spectral composers – it is obvious that the “spectral movement” can be understood as a critical response to serial music. The movement was indeed a contributing factor to the heralding of the post-serial era.[121] Spectral composers intended to create new *hierarchies* for pitch organization, thus signifying their disapproval of dodecaphonic and/or serial systems which – in their opinion – caused an unacceptable inflation of indiscriminate pitches. Spectral music was intended to be an alternative to the dominance of equitempered chromaticism, one that could open up new possibilities, rather than regress to the previously explored languages of neo-classicism or neo-tonality.[122]

As mentioned above, spectral composition principles primarily make use of material derived from the overtone series. The overtone (or: harmonic) series is a theoretically infinite scale consisting of resonant frequencies that occur in a vibrating string or air column. The overtones are by physical law whole-number multiples of their fundamental. The aspect of

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[119] William A. Sethares, *Tuning, Timbre, Spectrum, Scale* (London, 2005), 15
[120] Tristan Murail, ´Target Practice`, *Models & Artifice – The Collected Writings of Tristan Murail*, ed. Peter Nelson, Contemporary Music Review, Vol. 24, Parts 2+3 (2005), 149
[121] Other factors included the US-based „Minimal Music“ and the German „Neue Einfachheit“ movement introduced by Wolfgang Rihm and Hans-Jürgen von Bose.
[122] Note the similarities to the philosophies of Partch and Johnston.

an (at least theoretically) infinite source of pitch material is one of the most striking characteristics of the overtone series which requires the spectral composer to define qualitative methods of how (and what) to choose from this material. Unlike Harry Partch, whose methods embraced a scalar approach derived from extended triadic ratio models, the spectral composers applied composition methods which Gerald Resch described as ´biomorphic`.[123] These methods generally include a Fourier Analysis (FFT) of an (instrumental) spectrum in order to determine hierarchies of partials, areas of formants (i.e. partials with strongest acoustic energy within a spectrum), frequencies, pulsation, and thresholds of interference, sound saturation or elements of distortion.[124] This information can then be used to *re-synthesize* spectra, for instance, by allocating the partials of a spectrum to various instruments. Since many of the elements described above define the *timbre* of a sound, this "orchestrating technique" enables the spectral composer to re-synthesize and compose with timbre.[125] Tristan Murail pointed out the importance of timbre and its inseparable connection to harmony on many occasions – his concept of "harmony-timbre"[126] describes the two parameters as hybrid structures that combine the characteristics and qualities of the two initial concepts. According to Murail timbre is the ´addition of basic elements, pure frequencies, sometimes white noise bands`[127] while harmony is defined as an addition of timbres. Murail thus points out that ´there is theoretically no difference between the two concepts.`[128] Murail makes frequent use of re-synthesis, since such operations provide him with those hybrid structures; here, the timbral characteristics of the re-synthesized spectra are mutually conditional to the construction of harmony.

Apart from re-synthesizing instrumental spectra, composers like Grisey and Murail also applied algorithms in order to construct artificial spectra. The most frequently used techniques include *Frequency Modulation* and *Ring Modulation/Combination Tones*.

12 Frequency Modulation

The term "*Frequency Modulation*" refers to an operation, developed by John Chowning,[129] which enables the composer to ´create a spectrum through the modulation between two

[123] Gerald Resch, ´Natur Plus X: Die spektrale Musik des Groupe L´Itinéraire`, *ÖMZ* (06/1999), 17
[124] Resch, op. cit, 16
[125] A well known and acoustically evident example for this phenomenon is the beginning of Gérard Grisey´s piece *Partiels* which is based on the re-synthesis of the spectrum of the low E of a trombone.
[126] T. Murail, ´Villeneuve-Lès-Avignon Conferences, Centres Acanthes, 9-11 and 31 July 1992`, *Models & Artifice – The Collected Writings of Tristan Murail*, ed. Peter Nelson, Contemporary Music Review, Vol. 24, Parts 2+3 (2005), 213
[127] T. Murail, ´Spectra and Sprites`, *Models & Artifice – The Collected Writings of Tristan Murail*, ed. Peter Nelson, Contemporary Music Review, Vol. 24, Parts 2+3 (2005), 138
[128] Murail, op. cit., 138
[129] John M. Chowning (*1934), American composer and computer scientist

frequencies.`[130] Through the process of modulation, the first frequency, called the *carrier frequency*, is altered by the second frequency, the *modulating frequency*. The resulting spectrum is made up of the summation and difference tones yielded by the modulation. François Rose has introduced a simplified version[131] of Chowning´s original equation for the frequency modulation[132]:

$$F(i) = [c \pm (m \odot i)]$$

The symbol c stands for *carrier frequency*, m for *modulating frequency*, and i for the *index of modulation*. If, for instance, the composer wanted to create a spectrum containing eight different pitches based on G4 (= 392 Hz) modulated by C#4 (= 277.18 Hz)[133], he would get the following results:

Summation Tones	**Difference Tones**
669.18 Hz (i = 1)	114.82 Hz (i = 1)
946.36 Hz (i = 2)	162.36 Hz (i = 2)
1223.54 Hz (i = 3)	439.54 Hz (i = 3)
1500.72 Hz (i = 4)	716.72 Hz (i = 4)

Fig.77: Summation and difference tones

Translated into pitches, the composer gains the following material:

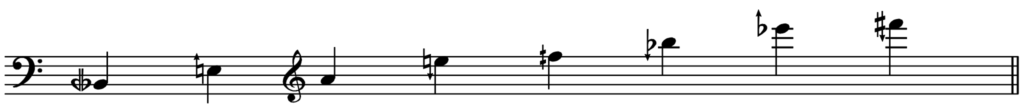

Fig.78: Spectrum based on FM

This resulting spectrum is an "artificial" inharmonious spectrum that does not adhere to the natural interval proportions of the overtone series. Instead, the technique of Frequency Modulation enables the composer to create a basic artificial spectrum that can be used, for instance, as a starting point for a composition. Possible methods of developing the material include transpositions, augmentations, an additional FM based on two pitches from the spectrum, etc. One of the most striking capacities of this technique is that it provides the

[130] Francois Rose, ´Introduction to the Pitch Organization of French Spectral Music`, *Perspectives of New Music* (1996), 30
[131] The part of the equation dealing with the amplitude has been left out.
[132] Rose, op.cit., 30
[133] The frequencies refer to equal temperament where A4 = 440Hz.

composer with a multitude of unique microtonal intervals that can form the basis for the melodic and harmonic construction of a work. In addition, the process of generating pitches is focused, and the goal of an efficient and economic use of pitch material is thereby met.

13 Combination tones

Combination tones result from the addition and subtraction of two frequencies, yielding summation and difference tones, respectively. The technique of creating combination tones could therefore be described as the ´acoustical counterpart to ring modulation.`[134] Spectral composers like Gérard Grisey have used this concept to create hierarchies within their pitch collections by arranging the combination tones in mathematical order. The fundamental frequencies thereby represent the starting point. The summation and difference tones derived from those frequencies are first-order combination tones, whereas those gained from the adding and subtracting of first-order frequencies are considered second-order combination-tones. Grisey referred to these lower-order combination tones as ´shadow-tones`[135].

Fundamentals		**523.25 Hz**		**440 Hz**	
1st-order		963.25Hz (St1) (A+B)	83.25 Hz (Dt.1) (A-B)		
2nd-order	1046.5Hz (St.1) (2A+2B)	1486.5Hz (St.2) (2A+A)	1403.25Hz (St.3) (2A+B)	523.25 Hz (St.4) (2B+B)	606.5Hz (St.5) (2B+A)
	880Hz (Dt.1) (2A-2B)	440Hz (Dt.2) (2A-A)	523.25Hz (Dt.3) (2A-B)	356.75Hz (Dt.4) (2B-B)	440Hz (St.5) (2B-A)

Fig.79: Set of combination tones (excerpt)

The chart shows the first- and second-order combination tones between pitches A4 (440Hz) and C5 (523.25Hz). It also suggests the vast amount of material that can be gained from this technique, owing to the fact that *all possible combinations* are used to create difference and summation tones from the second-order material onwards. The challenge of maintaining economic use of material again becomes clear with combination tones. As with those discussed before, this concept narrows down available material, but at the same time provides a composer with seemingly infinite possibilities. It is therefore necessary to preemptively establish the extent to which one will make use of such techniques.

[134] Rose, op.cit., 20
[135] Rose, op.cit., 21

14 Harmonicity, inharmonicity, and subharmonicity

The preceding paragraphs have addressed three central methods of pitch generation in spectral music. The following will focus on techniques used to develop previously generated material throughout an actual composition.

The concepts of harmonicity, inharmonicity, and subharmonicity consider the harmonic qualities of material from the overtone series. In the context of spectral music, the term *harmonicity* refers to a spectrum that contains exclusively whole-number multiples of its fundamental. Such a constellation can be found naturally in the overtone series, but also in the instrument spectra of string or wind instruments. An *inharmonious spectrum* contains elements that are not whole-number multiples of the fundamental. In other words, there are either additional pitches in between the natural proportions or certain partials are missing. For example, the spectra of many percussion instruments are inharmonious (the highest degree of inharmonicity being described as “noise”).

Fig.80 shows a gradual progression from a harmonious spectrum (based on the proportion 8:9 from the overtone series on C) to one becoming more and more inharmonious:

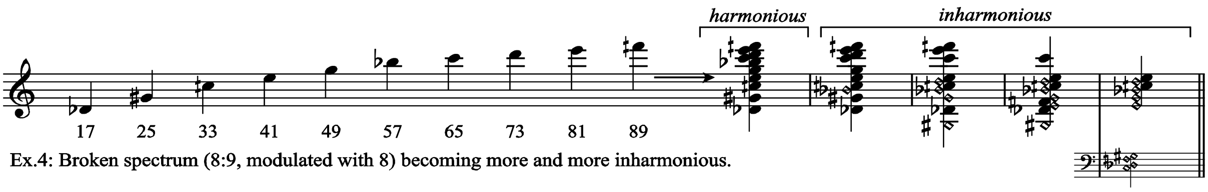

Fig.80: Broken spectrum

Gradually, several partials are transposed downward and thus placed into a “wrong” octave, thereby interrupting the integer-based series of proportions. The final chord represents a rather inharmonious spectrum: Partials 33 and 41 are the only components left at their original (correct) position. Gradual shifting between harmonious and inharmonious spectra is a very common technique in spectral compositions. For instance, the entire work “Prologue” for Viola by Gérard Grisey presents a single extended metamorphosis from a harmonious to an extremely inharmonious spectrum.[136]

A further variant can be found in the use of *subharmonious spectra*. These contain an inverted order of intervals from the overtone series (large intervals in the high register, small intervals in the low).

[136] The composer uses only a single spectrum (on E). The work explores this spectrum up to the 72nd partial before the final bits of harmonicity become absorbed by aggressive noise (inharmonicity).

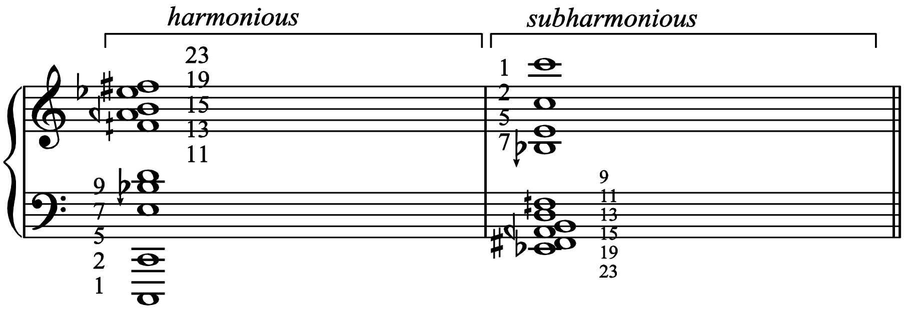

Fig.81: Harmonious and subharmonious spectra

Fig.81 shows the transition from a harmonious to a subharmonious spectrum which has simultaneously become inharmonious, owing to the fact that the order of intervals has partly been changed (11, 9, 15, 13, 23, and 19).

It should be noted that all the aforementioned concepts and techniques can be *combined* and *varied* to create a highly differentiated and multifaceted musical language.[137]

All these spectral techniques generate hierarchical microtonal pitch sets that can take various shapes:

- Just intervals from the overtone series
- Constituents of instrumental spectra
- Pitches resulting from algorithmic procedures

However, unlike Partch´s or Johnston´s approaches, which display a strong focus on (microtonal) pitch relations, microtonality is only *one* highly integrated musical parameter among others in spectral music. Composers like Grisey and Murail therefore did not treat their microtones as carefully as, for instance, Partch. There is in fact a noticeable discrepancy between systematic precision and practical imprecision: microtones are frequently approximated to the nearest eighth- or quarter-tone or at times even omitted completely.[138]

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[137] Grisey, for instance, composed complex modulation processes consisting of progressions containing both harmonious, inharmonious, and subharmonious spectra in his *Modulations for 33 musicians* (1976/77).

[138] See section VII of Murail´s *Désintégrations* (1982/83) in which all microtonal intervals are approximated to the nearest semitones in order to facilitate performance at the required tempo.

Murail acknowledges this:

> ´[…] frequencies expressed by the speed of their periodic vibrations (Hertz) are inconvenient.[…] I will […] represent the frequencies through […] approximations using tempered divisions of the octave.`[139]

Furthermore, Murail states that ´approximation to the 1/8-tone is sufficiently precise.`[140] And, hereby almost contradicting himself, ´In my works, I generally limit myself to the quarter-tone.`[141] Considering the microtonal intricacies of a pitch system based on, for instance, Frequency Modulation and the fact that the size of an eighth-tone amounts to 25 cents (a clearly distinguishable interval) one has to express doubt whether the practical realization can do justice to the theoretical concept.

One of the most important achievements of spectral music is its exploration of what Murail calls ´frequential harmony`- ´a harmony liberated from the constraints of scales and other grids habitually applied to the continuum of frequencies.`[142] Characteristic for spectral music is indeed its strong vertical (non scalar) sense and its focus on harmony-timbre. Typical are also concepts of extending perceived time: acoustic processes that naturally occur in a split second are explored in stretched time so that micro-elements (such as details of a spectrum) which usually cannot be perceived are made audible – the music proceeds in "microscopic slow-motion". [143]

15 Post-spectralism

Somewhat analogous to the manner in which post-serialist aesthetics followed serialism, an ongoing period of *post-spectralism* entered after what could be called the heyday of spectral composition. One of the many problems of the term "post-spectral" is its vagueness regarding the timeline of this new era. Typically, an aesthetic response (either affirmative or negative) to a substantial and dominant artistic direction sets in once the original aesthetic has developed a *style* and thus became prone to categorization. I would argue that this condition would have applied to spectral music by the late 1980s; however, both the aesthetic and works of spectral music did not begin to receive a more global reception before the untimely death of Gérard Grisey in 1998. It is therefore virtually impossible to name a starting point for which the internal and external conditions are congruent. The expression

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[139]T. Murail, ´Villeneuve-Lès-Avignon Conferences, Centres Acanthes, 9-11 and 31 July 1992`, *Models & Artifice – The Collected Writings of Tristan Murail*, ed. Peter Nelson, Contemporary Music Review, Vol. 24, Parts 2+3 (2005), 193
[140] Murail, op. cit., 194
[141] Murail, op. cit., 196
[142] Murail, op. cit., 196
[143] This particular feature has been subject to ongoing criticism: a frequent allegation was/is that of "aesthetic one-sidedness".

"post-spectral" can therefore only be partially applied as an epochal term. As an aesthetic term it describes a compositional direction that references one or more aspects of spectral aesthetic and/or technique. Common references include the processing of elements from the overtone series (or related just intonation principles), variations on harmony-timbre and the re-synthesis of spectra. At the same time an implementation of greater liberty or (where possible) greater rigor towards those techniques can frequently be observed – techniques are transformed, developed further, merged with other non-spectral concepts etc. Post-spectral aesthetics, however, have not replaced the original spectral composition practice which is being pursued simultaneously to this day.[144]

Countless composers have dealt with post-spectral issues since the heyday of the French Spectral School. In the following paragraphs I will focus on French composer Philippe Hurel, who is associated with what is sometimes called the "Second Generation French Spectral School", and German composers Manfred Stahnke and, as a special case, Hans Zender.

16 Philippe Hurel and Manfred Stahnke

Hurel (b.1955) broke with the traditional spectral method of applying continuous gradual harmonic progressions by replacing it with the (re-)introduction of motives and their subsequent variation. He further applied formal models involving structural transitions including miniatures that can be played in different orders as part of moment form concepts. Most importantly he merged a contrapuntal writing style with spectral techniques by integrating ´objects of a spectral nature within polyphonic forms`. [145] This way spectral methods became tools separated from their original purpose. One of the most noticeable characteristics of his music is the striking stylistic heterogeneity and ambiguity (e.g., counterpoint vs. timbre) that is the result of the merging of various different influences and techniques. Hurel names, for instance, spectral, serial, and jazz influences while rejecting any "neo" influence.[146] In terms of his pitch organization Hurel exclusively uses non-tempered microtones based on algorithmic procedures, and like Murail, avoids ´indexed scales`.[147] On a whole the spectral influences are clearly perceivable (such as in the use of harmony-timbre) in many of Hurel´s works but at the same time his music is stylistically

[144] Eminent figures of spectral composition include, of course, Murail and, for instance, German composer Wolfgang von Schweinitz.
[145] Guy Lelong, ´Interview with Philippe Hurel`, in the liner notes of: Philippe Hurel, *Six miniatures en trompe-l´œil, Leçon de choses, Opcit, Pour l´Image*, Ensemble InterContemporain, Alain Damiens, Ed Spanjaard (Adès, 1995), CD 204 562
[146] Lelong, op. cit., 35
[147] Lelong, op. cit., 10

very different due to various non-spectral influences, particularly in the realms of structure, rhythm and counterpoint.

Manfred Stahnke´s (b.1951) aesthetic, on the other hand, is situated somewhere between the concepts of Partch/Johnston and those of Grisey and Murail. Like the former, Stahnke also works with concepts of extended just intonation, however, he extends the limits further up to 17-, 19-, and 23-limits in order to explore very complex harmonic relations.[148] He is particularly interested in material that is generated by the rarely used "utonalities" of the higher limits.[149] Further main concerns include the exploration of the harmonic and melodic tension between pure and "contaminated" intervals and the effect that harmonic beats have on timbre.[150] Like Ben Johnston, Stahnke rejects an aesthetic that is based entirely on pure intervals without beatings. On the contrary, he is of the opinion that certain harmonic ´impurities "ensoul" the sound`.[151] He therefore allows for approximations of just intervals when traditional instruments are being used. In addition he frequently makes use of concepts related to harmony-timbre while also being strongly influenced by non-Western music.

Both Hurel and Stahnke represent what could be called a common type of post-spectral composer, one that merges many different influences and who consequentially creates varied works based on specifically tailored systems. A similar statement could be made about composers such as Marc-André Dalbavie (b.1961) or Georg Friedrich Haas (b.1953) who both have strong ties to the aesthetics and techniques of the French Spectral School, but who at the same time incorporate other influences as well.

17 Hans Zender´s *Gegenstrebige Harmonik*

In 2000, German composer Hans Zender (b.1936) published his treaty *Gegenstrebige Harmonik* ("agonistic harmony"), which, at this point of time, seems to be one of the most influential post-spectral tone-systems introduced in recent years. The central purpose of this system is to provide pitch materials that enable the composer to explore the balance ´between centripetal and centrifugal energies` in a composition;[152] in other words, to allow for a new balance between linearity and verticality of a (microtonal) pitch language. Zender´s quintessential motive for creating this system is founded on his critique of atonal (non-hierarchical) pitch systems which, from his point of view, display an inability to either

[148] M. Stahnke, ´Mein Weg zu Mikrotönen`, *Mikrotonale Tonwelten*, ed. Heinz-Klaus Metzger and Rainer Riehn (München, 2003), 136
[149] Stahnke, op. cit., 136
[150] Stahnke, op. cit., 133
[151] Stahnke, op. cit., 138
[152] Hans Zender, ´Gegenstrebige Harmonik (2000)`, *Mikrotonale Tonwelten*, ed. Heinz-Klaus Metzger and Rainer Riehn (München, 2003), 172

recognize and/or express the qualitative differences between intervals in favour of a ´chromatic mush`.[153] Zender extends his critique also towards equal temperament by claiming that thinking in equal temperament is an ´uncritical acceptance of a positivistic attempt to transform an organic existence into an artificial object.`[154] This statement certainly implies a critical attitude towards Murail´s treatment of microtones while simultaneously showing an affinity towards the viewpoints of composers like Partch and Johnston.

Zender´s theory borrows a particular aspect from the method of *ring-modulation*, namely the addition of the respective summation and difference tones of a previously defined interval. This primary interval is thus treated as an excerpt from an imaginary spectrum while the difference and summation tones function as its additional partials. By means of multiple (ring-) modulations Zender generates a certain number of pitches which he, once arranged as a pitch set, identifies as ´gebrochene Spektren` ("deformed spectra").[155]

18 Zender´s *Deformed spectra*

The concept of creating "deformed spectra" to extract a limited quantity of material resembles the frequency modulation to a great extent, as both concepts focus on the modulation of two pitches. The major difference lies in the fact that "deformed spectra" are exclusively derived from the process of modulating two pitches from the *overtone series*, whereas for frequency modulation any two can be chosen. Logically, it follows that "deformed spectra" are initially always natural, harmonious spectra, whereas the spectra gained from frequency modulation are "theoretical" and often inharmonious. Fig.82[156] shows the modulation of two intervals with the proportion 4:5 (major third) from the overtone series based on ´C1`.

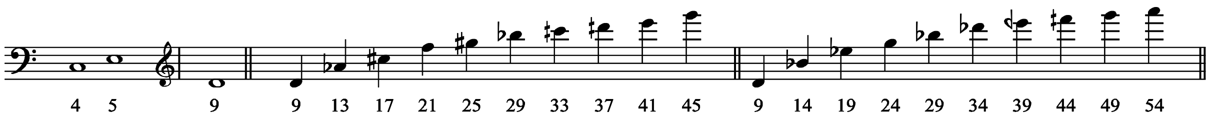

Fig.82: Deformed spectra based on 4:5

The two extracts from the overtone series on ´C` result from the three addition processes that were applied to the ´parental`[157] pitches: the original pitches were first modulated with each other (4+5), followed by the modulations of the resulting summation tone (9) with both

[153] Zender, op. cit., 169
[154] Zender, op. cit., 169
[155] Zender, op. cit., 189
[156] Zender, op. cit., 190
[157] Zender, op. cit., 189

parental pitches. Again, as with frequency modulation, the composer must define the index of modulation to limit the results (i = 10 in fig.82). Given that the modulation process has (in this case) been applied in accordance with the proportions of the overtone series, the results will exclusively consist of components that are whole-number multiples of the fundamental (e.g., 1:2:3:4:5:6 etc). In other words, the spectra will be *harmonious*.
Further techniques exist to expand upon the process of creating deformed spectra. Fig.83 illustrates one such technique: *multiple modulation*.

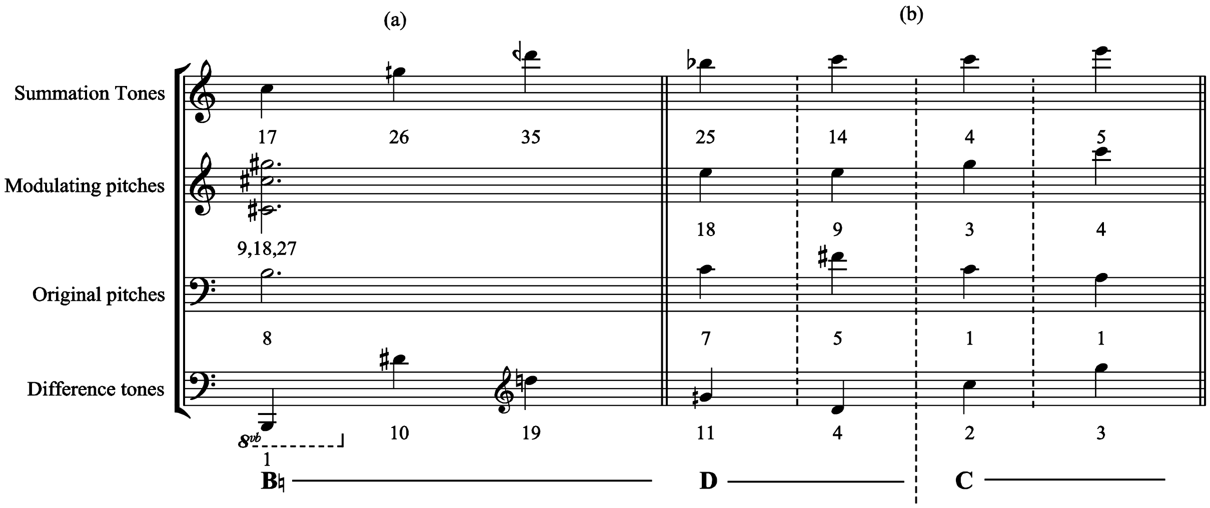

Fig.83: Multiple modulation

In fig.83 the original pitch (partial 8 from the overtone series on ´B`) is modulated by three pitches that form multiple integers of each other (9, 18, and 27). Part (b) in the above example illustrates the simultaneous modulation of pitches from two overtone series (fundamentals ´D` and ´C`), thus creating a *double-spectrum*. The application of these techniques enables a composer to create highly complex pitch collections containing components of multiple spectra. The number of original pitches, modulating pitches, and spectra used can powerfully influence the harmonic and melodic densities of particular textures in a composition (including cluster-like "noisy" sound-worlds); one can virtually build a whole piece based on an organic pitch system from this premise.

Like his predecessors, Zender had to address the issue of how to represent the numerous pitches that his system generates. He observed the ´irresolvable contradiction` between the equitempered twelve-tone scale and the nature of the pitches he obtained from his interval modulations.[158] As a solution Zender suggested to integrate the new pitches into the equidistant twelfth-tone system (72 twelfth-tones within the octave), which, as we have seen, closely approximates most of the just intervals within the 11-limit. It, however, cannot effectively approximate the 13-limit (this would require the more refined 24th-tone system

[158] Zender, op. cit., 178

with 144 pitches per octave); Zender accepted this for the time-being and (more or less out of necessity) declared the thirteenth overtone and its multiples to become the new “diabolus in musica”.[159]

The undeniable advantage of this approach is that the *origin* of each pitch does not have to be communicated *through notation* since the pitches are integrated into an abstract scale consisting of equidistant pitches relating only to one another. The alternative approach – abandonment of equal temperament and thus representing the actual hierarchical contexts through the notation – would require a new and most likely very complicated notation method.[160] Zender´s notation, in comparison, is remarkably simple: the intervals are notated in approximation of their real value. The symbols (+)/(++) and (-)/(--) indicate two different degrees of raised or lowered pitches while arrows are used to describe quarter-tone deviations. Zender acknowledged that (with this approach) the clarity about the intended interval cannot be achieved through perfect intonation but rather through the musical context of the difference and summation tones which “inform” the ear about the context of each respective pitch.[161] Success or failure of a tone-system based on Zender´s methods will therefore depend to a significant degree on how effectively the composer manages to communicate the pitch contexts to the listener (the underlying pitch hierarchies may not have to be notated but they must certainly be composed!). This characteristic contributes to the “aesthetic openness” that Zender´s methodology provides: depending on the intervals (and the index of modulation) used for the modulation processes various very different sound structures can be generated. Some of them are reminiscent of pitch collections already used in previous epochs of great stylistic diversity, which led Zender to emphasize the connection between his theory and its potentials for “poly-stylistic” composition methods.[162] Independent of the manifold possibilities this method offers, the phenomenon that globally defines the system is its reliance on two fundamental pitches that are being modulated with each other and which thus lead to an agonistic branching out of pitches which are related to their fundamental(s) by shared construction principles.

[159] Zender, op. cit., 185
[160] German composer Wolfgang von Schweinitz chose this approach for his works and invented a notational system which uses 20 different accidentals (and their combinations) to describe various typical just intervals (ranging from the just major third 5/4 to, for instance, the 61-major seventh 61/32).
[161] Zender, op. cit., 207
[162] Zender, op. cit., 202