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´Microtonality in the Post-Spectral Era` (excerpt)

2.2 *LuftLinien*

2.2.1 Introduction

After the completion of *défraîchir*, whose pitch sets feature comparatively indeterminate microtonal intervals, I intended to focus on determining the importance of precise microtonal intonation for pitch material derived from the overtone series.

My interest in this subject had been evoked by my examination of Tristan Murail´s works for *non-detuned* solo piano (*Territoires de l´Oublie* and *Les Travaux et les Jours* in particular). These two works are predominantly concerned with concepts of resonance which allow the composer (at least at times) to produce and explore non-tempered microtonal overtones on a non-detuned piano. I came to the conclusion that this approach is most effective in situations that are harmonically non-complex, for example, when the strongest partials (formants) of a reiterated bass note (played at *fortissimo*) excite related strings which, as a result, begin to vibrate. In more complex situations, however, the material quickly becomes increasingly more ambiguous. It may be possible for an experienced listener to classify certain harmonic situations as spectral (i.e. based on material from the overtone series) because he or she relates certain interval constellations (usually those consisting of arrangements of lower partials) to a fundamental. However, the more complex these pitch relations, the more ambivalent they become due to their “misrepresentation” in equal temperament and/or their sheer harmonic complexity.

I felt that this (Murail´s) approach had been quite thoroughly explored both by him and other composers, and therefore decided to opt for a different procedure.

2.2.2 Spectral harmonies and Equal Temperament

One of the main initial objectives for *LuftLinien* was to create a spectral piece within equal temperament and thus without making use of the possibility to detune any of the piano strings. With this fundamental condition in mind it became clear that the chief concern had to be laid on aspects of psychology of perception, since both recognition and adjustment of those intervals that are “out-of-tune” in respect to just intonation, had to be rendered to a great degree by the listener. It is for this reason that one of the crucial compositional problems that needed to be addressed was the question of how this could be facilitated without having to compromise on the attractiveness of the pitch material: I wanted by all means to avoid a simple “wandering up and down” the overtone series, which so easily leads to complete predictability, and which to my ears occupies the momentum of “demonstration”. I decided that the application of *different degrees* of spectral recognizability had to be of major importance to the piece, meaning that at times the harmonic origin and consequentially certain microtonal deviations from equal temperament could deliberately be veiled or ambiguous. Those moments, however, in which the relation of the partials to their respective fundamental would be reasonably clear, could serve as reference points as they suggest an overall spectral context and thus remind an (analytical) listener to question the origin of the previously heard harmonies.

2.2.3 Golden Section and Fibonacci Sequence

The other main objective for this work was to set up a superordinate system which organizes most musical parameters. For this I chose the combined concepts of Golden Section and Fibonacci Sequence (note that the quotient of two consecutive Fibonacci numbers approaches the proportion of the Golden Section). Almost all musical parameters in this work (excluding rhythm) are based on this, as the Golden Section proportion (1:1.618033988…) is applied to many different layers on both macro- and micro-levels, so that a great degree of formal (fractal) self-affinity is achieved throughout the piece.

The structure of the work is organized as follows:

There are two macro-sections which relate to each other in the Golden Section proportion: Section I (bars 1-126 [duration: 4´20]) and Section II (bars 127-174 [duration: 2´40]). These sections are further sub-divided (all sub-divisions are organized according to the proportion of the Golden Section).

The following example demonstrates the formal organization of the beginning of the piece (bars 1-38):

Section I)1)a):

Duration: 100”
Tempo: q = 68
Number of q : 112.5

Fibonacci (quavers)	89	55	34	21	13	8	5
Crotchets	44.5	27.5	17	10.5	6.5	4	2.5
Meter	4/4 (10x), 3/4, 3/8	4/4 (6x), 2/4, 3/8	4/4 (4x), 2/8	4/4 (2x), 5/8	4/4, 5/8	4/4	5/8
Fundamental	G	G	G/D#	G/D#	D#	D#	D#

Fig.6: Structure section I)1)a)

This section introduces the main motivic material for the piece, i.e. repetitions, accented chords, rotating gestures, static harmonic fields and the confrontation of clear and blurred sounds (pedaling). The most pre-eminent characteristic of this section is probably the use of delicate and transparent high-pitched melodic lines (which the title *LuftLinien* [literally translated meaning “aerial lines”] refers to) that form the starting point for processes of continuous metamorphoses of the musical material throughout the piece.

Fig.6 illustrates the structural method I applied: an excerpt from the Fibonacci Sequence (89 to 5) determines the length of each sub-segment contained in this section. Note that each Fibonacci number refers to the variable “quaver”. Each of these segments is assigned a certain pitch material: the pitch organization itself is based on material from the overtone series while the criteria for the respective choice of pitches are derived from the numbers of the Fibonacci Sequence. I used altogether four different spectra (´B nat.`, ´D sharp`, ´F sharp` and ´G nat.` – with ´B nat.` serving as the “tonic” of the piece). Initially, the following partials were chosen:

1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144

(i.e. eleven numbers from the Fibonacci Sequence).

Apart from this original sequence, several dilations and compressions were used (e.g., partials 2, 4, 6, 10, 16, 26, 42, 68, 110, 178 [original x2] or 1, 2, 3, 4, 5, 7, 9, 11, 14, 18, 23, 30, 39, 51, 66, 86 [proportion 1:1.3] etc, including their combinations) as a means of developing the pitch material. Due to the characteristic of the Fibonacci Sequence, the interval of the “natural” seventh (the seventh partial and its octaves) is almost never used in the piece which has a significant impact on the sound-world of this work.

Material based on one of the above-mentioned fundamentals is then allocated to each of these sub-sections. The table shows that the piece begins “in G” followed by a modulation to ´D sharp`; the next section (bars 39-65) simultaneously explores material based both on ´D sharp` and ´F sharp` which results in the use of double spectra. The next section is dominated by highly ambiguous triple spectra based on ´F sharp`, ´G nat.`, and ´B nat.` (bars 66-98). The last sub-section of the first macro-section is dominated by material based on ´F sharp` and eventually modulates to ´B nat.` (bars 99-126). Unlike the first, the second macro-section remains (harmonically) static as its material is exclusively derived from scales based on ´B nat.`.

2.2.4 Pitch ambiguity

The beginning of *LuftLinien* shows a deliberate resemblance to the beginning of *défraîchir* as both pieces start out featuring rather sparse high-pitched textures that gradually become denser and eventually transition into lower pitch regions. Despite this obvious similarity,

LuftLinien nevertheless represents, in some ways, the counterpart of *défraîchir*. One of the main distinctions between the two pieces is that the material of the latter continuously undergoes processes of deconstruction whereas that of the former is transformed in a constructive manner. In other words, the "negative destructive aspect" that is of such significant relevance in *défraîchir* is completely absent in *LuftLinien*. This "reversed variant" of a compositional model can be identified in several different ways in the first section of *LuftLinien*. The pitch repetitions in bars 1-8, for instance, are gradually transformed into melodic progressions (bars 8 ff.) – a method of motivic growth. The use of the sustain pedal gradually adds a vertical layer to the melodic lines (compare bars 16 and 22ff.); the material thereby receives an additional vertical layer before being transformed into primarily harmonic material (chord progressions) at the beginning of the next section (bar 39) – a method of constructive conversion.
The highly ambiguous pitch material of the beginning is carefully guided into a recognizable context. After establishing this context, the material is extended through the introduction of additional spectra. This method of *retroactive clarification of pitch contexts* is one of the principle methods I was experimenting with in this piece. This procedure could be described as the reversal of the typical traditional composition method where key clarification is achieved through the use of cadences right at the *beginning* of a piece.

The first section is defined by three different aspects:

- A continuous process of acceleration governed by the Golden Section proportion: the sub-sections are reduced in length according to numbers from the Fibonacci Sequence: 89, 55, 34,…,5;
- Two main gestural transformation processes: pitch repetitions are transformed into melodic lines are transformed into chords;
- The establishment of a pitch set containing ambiguous material (89), the clarification of its origin (55), and eventually its gradual harmonic extension through the addition of further spectra based on different fundamentals (34, 21);

The following analysis will focus almost exclusively on the third aspect and the phenomenon of retro-auditive pitch contextualization in particular.

Fig.7 on page 32 shows an analysis of the pitches featured in the first nine bars of the piece. Within these nine bars the entire pitch set used for sub-section [89] (bars 1-15) is introduced; the remaining bars of the section (bars 10-15) merely reiterate the previously introduced pitch material through the development of musical gestures. I used six different pitch segments all of which were derived from the overtone series on ´G nat.`. The selection criteria followed the numerical orders of various series based on the Fibonacci Sequence.
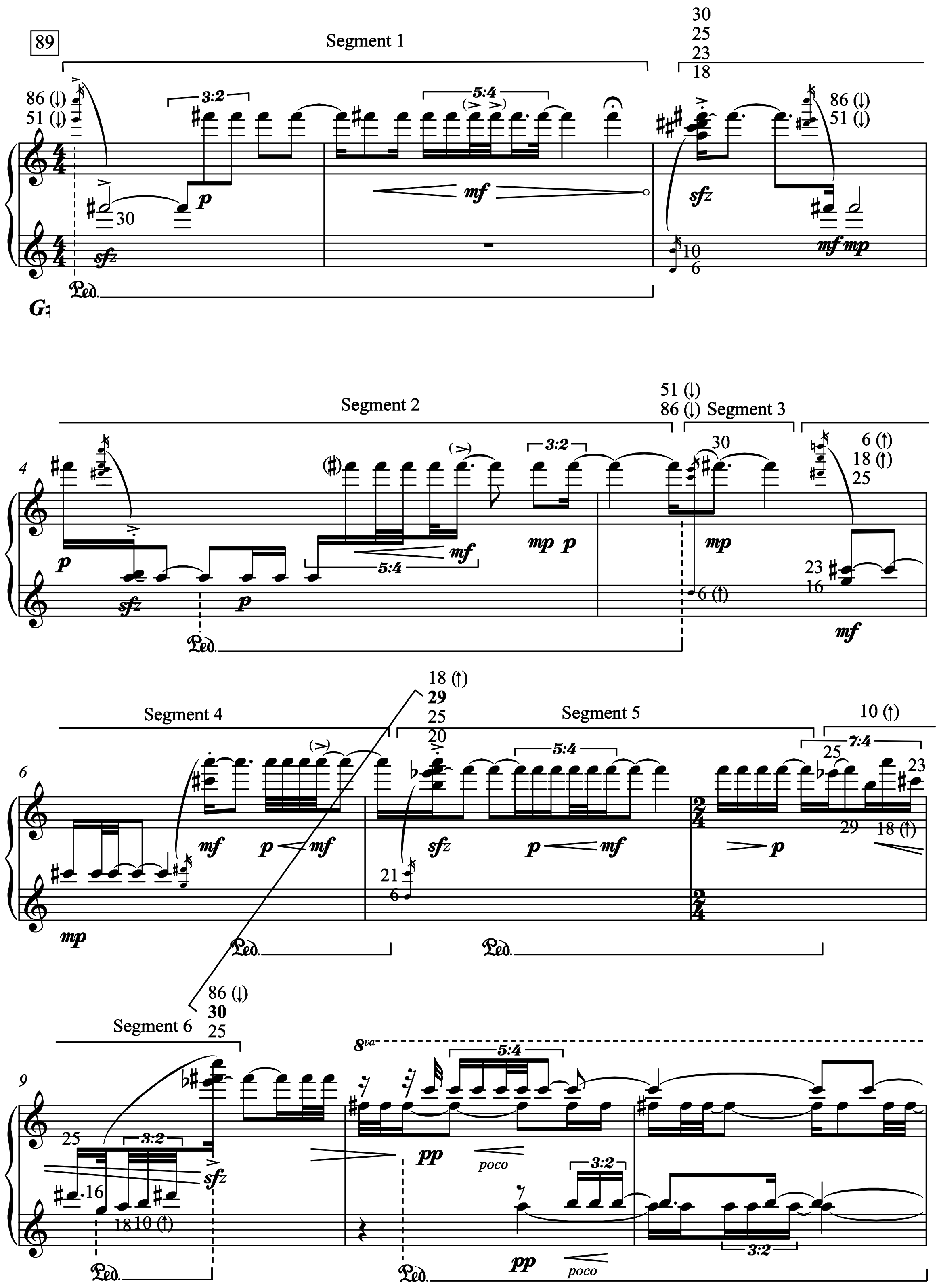
Fig.7: Pitch analysis bars 1-9

The three pitches in segment 1 are derived from a compressed version of the Fibonacci Sequence (the original proportion of 1:1.618033988… is replaced by the proportion 1:1.3 [see p.30]). Note that in order to clarify the origin of pitches I have dispensed with using numbers of overtone multiples in those cases where octave transpositions have been used; instead there are arrows which indicate when a pitch is not in its original octave. The spectral excerpt in segment 1 contains two pitches that are placed an octave too low. While 86 is the whole-number multiple of 43, 51 cannot be described as a whole-number multiple of another partial; technically speaking this spectral excerpt would therefore have to be considered inharmonious. This statement, however, is irrelevant from an acoustic perspective as this is the very first event in the piece for which the listener has not yet been given a horizontal context (i.e. other events to compare it to) so he or she lacks a suitable reference point. Furthermore, this particular chord is ambiguous regarding the identity of its “tonal origin”: it could, for instance, be based on either ´F sharp` or ´D nat.` (for the latter the top ´C` would have to be interpreted as a multiple of the natural seventh) or it might not have any hierarchical connotation at all. As a matter of fact, the chord is based on the (acoustically rather unlikely) ´G nat.`, but since any lower partials which could identify ´G` as the fundamental are missing, this connection cannot be made by the listener at this point. If a specifically detuned piano was used it would be possible to at least hint at the origin of the pitches by means of microtonal interval differentiation. The audio example features three potential versions of this chord (**❶**, **Tr.2**):

- Non-microtonal equal temperament (the way it will sound in an actual performance of this piece).
- Just intonation based on the hypothetical fundamental ´D nat.`: the ´C` now functions as the 56^{th} partial and thus sounds 31 cents flat, the ´E` represents partial number 36 sounding 4 cents sharp, and the sustained ´F sharp` serves as the 40^{th} partial and thus sounds 14 cents lower. Note that the 56^{th} is a multiple of the 7^{th}, the 36^{th} of the 9^{th} and the 40^{th} of the 5^{th} partial, and thus multiples of low, identity-generating partials. It is certainly conceivable that a listener might recognize this context and (subconsciously) add a virtual low fundamental ´D` when this chord is performed, as intended, on a piano tuned in equal temperament.
- Just intonation based on ´G nat.`: the ´C` now sounds 12 cents higher than the tempered ´C` and 43 cents higher than the one from the ´D`-spectrum; the ´E` sounds 7 cents higher than the tempered ´E` and 3 cents higher than the one from the ´D`-spectrum, and the ´F sharp` sounds 12 cents lower or 2 cents higher respectively. One would not expect a listener to adjust his or her hearing to a raised ´C` in this context. Since the remaining two pitches are virtually identical to their counterparts in the ´D`-spectrum one could argue that, if a hierarchical decision was made by the listener at all, it would most likely be one in favour of the fundamental ´D nat.`.

The harmonic progressions that follow in the subsequent bars are based on this assumption that the listener will most likely “misinterpret” the harmonic situation at the beginning of the piece by adding the “virtual fundamental” ´D nat.`.

The beginning of the second segment (bar 3) introduces five additional pitches (partials 6, 10, 18, 23, and 25). Three of these pitches (18, 23, and 25) are once again derived from the compressed Fibonacci Sequence and thus serve as a related harmonic formation below the ´F sharp` (partial 30). The introduction of the 23rd partial (´C sharp`) is of particular interest since it confronts the ´C nat.` of the beginning, which, if perceived as the seventh partial of a ´D`-spectrum, serves as a potent indicator of that particular tonality. The ´C nat.` is restated immediately thereafter thus creating an ambiguous harmonic situation regarding its underlying tonality. A further element that contributes to this ambiguity is the brief statement of partials 6 and 10 (´D nat.` – ´B nat.`). On the one hand, this grace note could be perceived as a lowered counterpart of the grace note in bar 1 – an analogous motive. On the other hand, it represents a first hint of the true tonality of the first section: partials 6 and 10 are multiples of partials 3 and 5 respectively and thus evoke a strong connotation of the fundamental ´G`.[8] The audio example compares two versions (ET followed by JI based on ´G nat.`):

❶, Tr.3

This harmonic counterstatement, however, is of the utmost brevity and becomes immediately opposed by the restatement of material suggesting a ´D`-spectrum. This impression is reinforced in bar 5 where the pitches ´D nat., C nat., E nat., and F sharp` (also in combination with the previously heard ´A nat.` in bar 4) clearly suggest ´D nat.` as the fundamental. This brief moment of apparent harmonic clarity is, however, once again immediately challenged by the next chord (bar 5, fourth beat) where, for the first time in the piece, a multiple of the fundamental ´G nat.` is heard (partial 16). Furthermore, the ´C sharp` (partial 23) once again confronts the previous ´C nat.`.

This method of comparing possible ´D nat.` and ´G nat.` connotations continuously features in the following bars (see, for instance, the grace notes in bars 6 and 7 respectively), while the material is further extended. Particularly noteworthy in this context is the introduction of a further confrontational ambiguity analogous to that of ´C` and ´C sharp`: in bars 7 and 8 the prominently featured ´F sharp` (partial 30) is challenged by partial 29 (a raised ´F nat.`). One could theoretically interpret this ´F nat.` as partial 28 and thus as a multiple of the 7th partial of the ´G`-spectrum. I would insist not to interpret it that way, not only because the ´F sharp` is reintroduced shortly thereafter in bar 9, but also because the attentive listener

[8] Note that partials 6 and 10 are not part of the compressed Fibonacci Sequence; they are derived from an augmented version (based on the ratio 1:2 instead of 1:1.618033988…). Not only does the chord audibly refer to another fundamental, it actually is a “foreign matter” due to its different origin.

should by now have become aware of the gradually emerging harmonic complexity of the material (symbolized through the *co-existence* of partials like 29 and 30 or 86 and 23). The following sub-section ([55] bars 16-24) clarifies that all these initially ambiguous pitches are indeed part of just *one* complex spectrum. It is the gradual unfolding of this reality that is the quintessential harmonic idea behind the first section.

2.2.5 Retroactive harmonic clarification

At the beginning of the second sub-section, the fourth partial of the ´G`-spectrum is introduced:

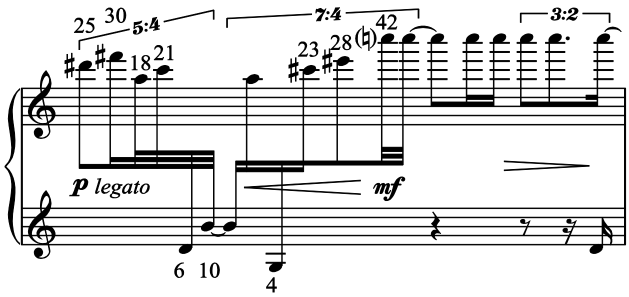

Fig.8: Harmonic clarification (bar 16)

In conjunction with partials 6 and 10 this multiple of the fundamental quite clearly defines the tonality. All other partials that were explored in the previous section are now placed into *one* harmonic context. This contextualization changes the perception of the previously heard material, which becomes particularly evident when the cent-deviations from equal temperament are examined:

Partial	4:	± 0 cents
	6:	+ 2 cents
	10:	- 14 cents
	18:	+ 4 cents
	21:	- 29 cents
	23:	+ 28 cents
	25:	- 27 cents
	29:	+ 30 cents
	30:	- 12 cents
	43:	+ 12 cents

The chart shows that the upper partials that defined the material of the first sub-section, will sound noticeably out of tune on the piano (see comparison between representation of partials 4, 6, 10, 18, 21, 25 in (a) ET and (b) JI; ❶, **Tr. 4**). The three lower partials unmistakably define the identity of the spectrum and the higher partials are thus "forced" to become part of the ´G`-spectrum. As a result of this constellation the human ear now ceases its attempts to interpret certain pitches as lower partials of other fundamentals and instead commences to understand the higher pitches as rather more distant partials of the fundamental ´G`. In other words, the listener now acknowledges the reinterpretation and hierarchical classification of the pitch material. This is mainly achieved through the carefully composed pitch context. I believe it is more than doubtful though that a listener´s ear would, in addition, be capable of adjusting the approximated intervals and thus create an *accurate* version of the harmonic field. It is probable though that listeners might detect an “out-of-tune-ness”, a sensation resulting both from the previously explored context of pitch ambiguity and the lack of true harmonicity (i.e. acoustic periodicity) caused by inaccurate intonation.

The function of the following bars (17-24) is to confirm this harmonic status; the harmonic material therefore remains static over the course of these bars while the main focus is shifted towards the development of melodic gestures.

2.2.6 Double-spectra

The following sub-section ([34] bars 25-29) introduces a new element: after the establishment of the ´G`-tonality excerpt, a spectrum based on the fundamental ´D sharp` is added.[9] This procedure leads to the development and subsequent exploration of double-spectra.

Fig. 9 illustrates the introduction of the ´D sharp`-spectrum. At first, the material derived from the ´G`-spectrum still remains dominant: all seven pitches have been used prior to this in the previous section and therefore give an impression of familiarity. Contrary to that, the two newly introduced pitches from the ´D sharp`-spectrum immediately change the character of the harmonic field: the ´D sharp` replaces the anticipated ´D nat.` in the left hand gesture while the ´G sharp` substitutes for the ´G nat.`. The following bars establish this new harmonic situation. It should be emphasized that, unlike in the first sub-section, a pitch ambiguity beyond the duality of the two spectra is carefully avoided due to the constant reiteration of multiples of the respective fundamentals (e.g., the fifth ´G – D` in bar 27 or the alternating repeats of ´D sharps` and ´G`s in bars 28 and 29).

[9] There are three reasons for the choice of ´D sharp`: (a) its direct relation to the “tonic” of the piece (it represents the fifth partial of the ´B`-spectrum), (b) its dichotomy with the “false” ´D`-spectrum, and (c) the potential for interesting combinations with pitches from the ´G`-spectrum.

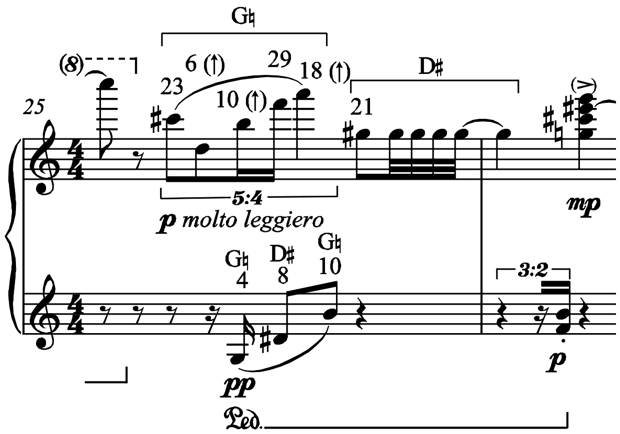

Fig.9: Double-spectrum (bar 25)

With each new sub-section (bars 30-34; 35-36; 37; 38) the material based on ´D sharp` gains in importance and continues to replace material from the ´G`-spectrum until the latter becomes completely assimilated at the beginning of the new section in bar 39.

Fig.10 shows an intermediate step of this procedure: in bar 30 the ´A sharp` (sixth partial of ´D sharp`, transposed up by an octave) has temporarily replaced the ´G` (eighth partial of ´G`). This shift of balance between the two spectra which is created through the suspension of a multiple of the other fundamental is further enhanced through the repeated use of the second partial of ´D sharp` (bars 31 and 32 respectively). The reiteration of the second partial gives the ´D sharp`- spectrum particular weight as it repeatedly reminds the listener of the new harmonic context. The ´D sharp` context is thus strengthened whereas the ´G`-spectrum loses momentum.

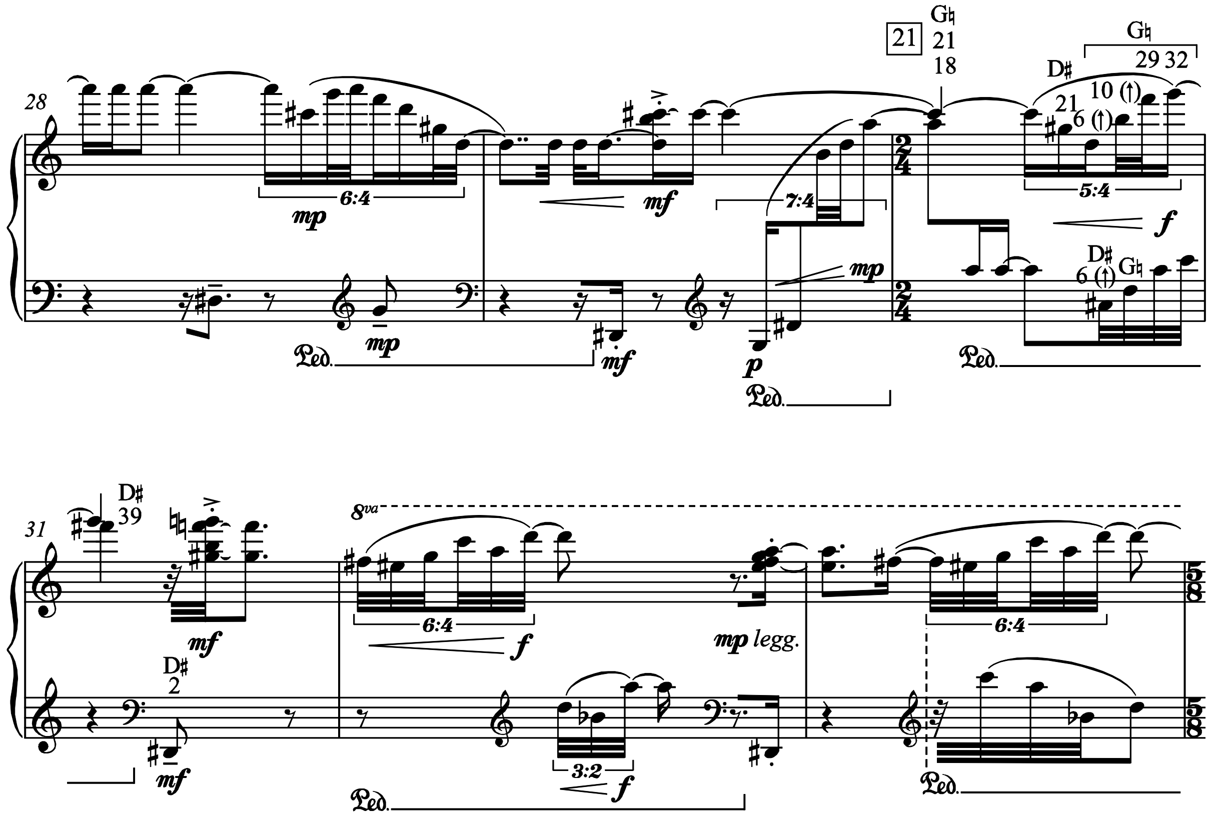

Fig.10: Bars 30/31

2.2.7 Ambiguity and clarity

As the above analyses have shown, the first section of *LuftLinien* concerns itself with the interplay of harmonically clear and harmonically ambiguous material. The “tonal” origin of the material is temporarily put into question when the lower partials of the respective fundamental are absent. Then again, at those moments that feature the introduction of lower partials, (unexpected) pitch hierarchies are suggested to the listener, which offer alternative perspectives on both previously heard and yet to be perceived material. The purpose of this first section therefore is to introduce the element of harmonic equivocation to the listener, to make him aware of the existence of the spectral contexts in the piece, and perhaps to guide him to adopt an attitude that defies the categorization of harmonic principles. One of my intentions for *LuftLinien* was to avoid using any previously categorized pitch material (i.e. “spectral” as in low-partial-chords and processes of growing inharmonicity, or “atonal” as in identifiable twelve-tone rows and their variations); instead I wanted to create a harmonic language that would elude these (strict) categorizations and preferably exist somewhere in between the extreme poles. These efforts result in a harmonic language that will, at times, appear somewhat veiled and elusive thereby maintaining a certain degree of distance between the music and the listener.

2.2.8 Harmonic double-layer

In contrast to the beginning, the following two sections (bars 39-65 and 66-98) mainly focus on the exploration of the vertical characteristics of the material. The first of these two sections reintroduces the concept of two spectra interacting with each other. Unlike in the first section, where the ´G´ and ´D sharp` spectra were carefully merged, here both spectra (´D sharp` and ´F sharp`) act independently as each one of them follows its own metric scheme (bars 47-59). The section begins with material based on ´D sharp` and uses an ascending excerpt of the Fibonacci Sequence (3, 5, 8, 13, 21, 34, 55). Contrary to this, the material based on ´F sharp` is introduced in bar 45 and follows a descending excerpt of the Fibonacci Sequence (55, 34, 21, 13, 8, 5, 3, and an additional 8 [bars 64-65], which serves as a transition to the next section).

Throughout the entire piece specific harmonic fields are assigned to all Fibonacci sub-sections; this way the exploration of the material based on ´D sharp` seems to decelerate (thus gradually becoming more repetitive), whereas that based on ´F sharp` seems to accelerate. This process of two materials “drifting apart” from each other is meant to allow for the listener to recognize the duality of the harmonic situation. The ability to perceive this is, however, impeded by the lack of microtonal pitch differentiation which occurs due to the mere interval approximation that results from performing this piece on an equitempered instrument. Two pitches, that are actually clearly different, will thus sound exactly the same and, given the harmonic complexity of this section, the human ear will often not be capable of making the adjustments necessary in order to ascertain the correct harmonic context. I believe it is possible to observe and perceive the relatedness of this material to that of the previous section (the methods of generating pitches have in fact not been altered), but I also believe that an exact determination of the harmonic origin of pitches would be virtually impossible. The presence of harmonic ambiguity thus continues and is reinforced even further in the following section.

2.2.9 Varying degrees of inharmonicity

Here a different approach to spectral pitch organization, namely the application of filtering processes, is explored. Chords consisting of very high partials are confronted with subharmonious structures; in both cases, the origin of the pitches involved remains obscure. Over the course of this section, however, the degree of harmonicity is gradually increased (particularly audible in the resonances caught by the sustain pedal [e.g., bars 79-80]), eventually leading to clearly perceivable spectra with rising and falling fundamentals (bars 99-126).

The following charts illustrate the harmonic progressions of this transitional section which eventually leads to the main Golden Section of the piece (bar 127):

Bars	099 - 101	101 - 102	102 - 103	104 - 105	105 - 107	108 - 109	109 - 110	110 - 111	112 - 113	113 - 115	115 - 116	116 - 117	118 - 121	121 - 122	122 - 124
Partials	1	1	1	2	2	1	1	1	1	1	1	1	1	1	2
	2	11	8	9	9	2	7	7	3	6	11	7	2	12	11
	7	14	12	11	11	9	10	10	5	10	13	11	11	13	15
	18	17	13	13	13	11	11	11	7	11	14	13	13	15	17
	21	24	15	19	15	13	13	13	9	13	17	20	18	17	19
	24		18	21	21	15	17	15	13	17	19	27	30	18	23
	25		19	30	27	17	19	19	15	21	20	38	38	19	27
	30				30	21		21	17	36	27	56	51	21	36
						27			26		43	64		24	38
									28					28	
Fundamental	Bν	Gν	Aν	Bν	Cν	Cν	Aν	G#	F#	Fν	D#	C#	Bν	Aν	Bν

Fig.11: Harmonic progressions bars 99-124

Partial	**No. of aggregates**
1	**12**
2/8/64	**9**
3/6/12/24	7
5/10/20	5
7/14/28/56	**10**
9/18/36	**10**
11	**11**
13/26	**13**
15/30	**11**
17	8
19/38	**10**
21	7
23	*1*
25	*1*
27	5
43	*1*
51	*1*

Fig.12: Aggregate characteristics

It is apparent that, in this section, the harmonic origin of all aggregates is clarified, since each aggregate contains its fundamental or second partial respectively. The main function of this section is to lead to (and prepare for) the climactic introduction of the central harmonic event of the piece, an aggregate (i.e. a perfectly harmonious structure) based on ´B nat.`, which features in the bars before and after the main Golden Section (bars 125-130). Furthermore, this material contrasts the previously heard subharmonious spectra by (re-) introducing a stronger sense of harmonic identity.

A further important aspect is that the partials which are predominantly used for these chords correspond to overtones that feature strongly in the low ´B nat.` of the piano. One could therefore describe this method of generating pitches as an abstract form of spectral re-synthesis since many of these chords serve as a harmonic-timbral pre-echoing of the final ´B nat.`- aggregate which marks the culmination of this harmonic progression.

The progression of harmonic fields commences with ´B nat.`, then rises to the ´C nat.` a ninth above the original ´B nat.`, and gradually descends back to ´B nat.`

Nearly all of the fifteen chords use related pitch materials: the most frequently used partials are 1, 7, 9, 11, 13, 15 and 19 (including their multiples). Less frequently but still commonly featured are partials 3, 5, 17 and 27 (this, again, includes their multiples). Further additional pitches include partials 23, 25, 43, and 51; however, each of them is only used once as a specific addition to a certain chord. All of these harmonic fields display varying degrees of inharmonicity. The least inharmonious structure is the one based on ´F sharp` in bar 112 (here, partial 13 [´D sharp 2`] sounds three octaves too low), while the most inharmonious chord is the one based on ´B nat.` in bar 122 (partials 11 [twice], 17, and 23 are placed in wrong octaves). It is no coincidence that the latter happens to be the most inharmonious chord: its purpose is to further enhance the effect of harmonic purity which the following chord (equally based on ´B nat.`) provides (bar 125). Despite the fact that the pitches cannot be accurately presented in equal temperament, the listener can still clearly perceive the different degrees of consonance between those two aggregates.

2.2.10 Imprecise intonation

Due to the predominance of chords featuring both fundamental and various lower partials, the imprecise intonation produced by the tuning of the piano is of greater consequence than anywhere else in the work. If the just intervals were intonated precisely the listener would experience the chords not as chords but as aggregates, i.e. single acoustic entities in which all constituents are more or less perfectly merged and thus perceived as a singular event of harmony-timbre. The way the chords have been written in this section is clearly suggestive of that phenomenon as the strong sense of verticality and the emphasis on sustained spectral harmonies invite the listener to explore the overall sense of harmonicity as well as the relationship of pitches towards each other. An adequate representation of the material would create a succession of harmonic fields exhibiting different degrees of “aggregate states” which in turn depend on the degree of (in)harmonicity each chord inhibits. A particular problem is the use of partials 11 and 13 which have to be rounded either up or down by approximately a quarter-tone when performed on the standard piano.[10] I made use of both

[10] This is reminiscent of Hans Zender´s remarks about the 13th partial: despite the different context partials 11 and 13 take on the role of the “Diabolus in musica” (see Appendix I, p.189).

options (i.e. rounding up and down) thereby following my intuition. The example below shows the previously mentioned chords, the first one representing the least, and the second one representing the most inharmonious chord of the section:

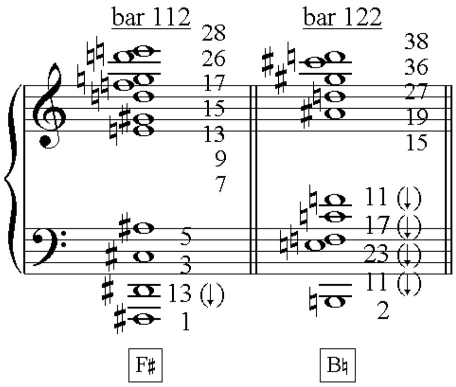

Fig.13: Inharmonious structures

❶, Tr. 5

The first chord (bar 112) simultaneously uses both "versions" of the 13th partial (´D nat.` and ´D sharp`) so that the initial *single* pitch is perceived as *two different* pitches; the correct pitch would be a ´D quarter-sharp` raised by an additional 9 cents. The audio example illustrates the acoustic differences between the renditions in ET and JI: the pitches of the latter sound more integrated (they are mostly actual whole-number multiples of the fundamental) thus making this harmonic field sound more like an aggregate, while the former sound (in ET) appears more like a chord with its clearly distinguishable components. There is also a stronger sensation of harmonicity in the JI version – this is mainly due to the precisely intonated lower partials 3, 5, 7, and 9. The one inharmonious element, the lowered 13th partial, also sounds significantly more dissonant in the JI context than in the ET context. The "correct" JI version provides an acoustic event that communicates an overall sense of integration and harmonicity which, however, includes *one* subtle disturbance caused by an inharmonious partial that penetrates the otherwise uninterrupted chain of whole-number multiples. In comparison, the ET version neither displays a strong sense of harmonicity nor does the inharmonious element cause a particularly noteworthy sensation of dissonance. Instead, the chord sounds rather balanced and somewhat "neutral", and fails to convey the sensation of the physicality of a truly harmonious spectrum. The absence of this phenomenon becomes even clearer with the second chord in bar 122. Those four partials that cause a strong sense of inharmonicity (partials 11, 23, 17, and again, 11) are severely microtonal compared to tempered semitones as partial 11 sounds a quarter-tone higher, 17 merely 5 cents higher while the 23rd partial sounds 28 cents higher. When reproduced with accurate intonation, this arrangement of pitches sounds very dissonant which is particularly evident due to the presence of the 2nd partial.

The audio example (❶, **Tr. 6**) shows the enormous difference between the renditions in ET and JI, and it becomes clear that the inherent inharmonicity of that particular harmony cannot be adequately reproduced in ET on the piano. It is also interesting to observe that the harmonious segment of the chord (partials 15, 19, 27, 36, and 38) sounds harmonious in itself in the JI version and thus introduces an extra layer. This level of differentiation is clearly lost in the ET version.

2.2.11 Harmonicity

The following example from bars 125/126 shows the central harmonious aggregate at the main Golden Section:

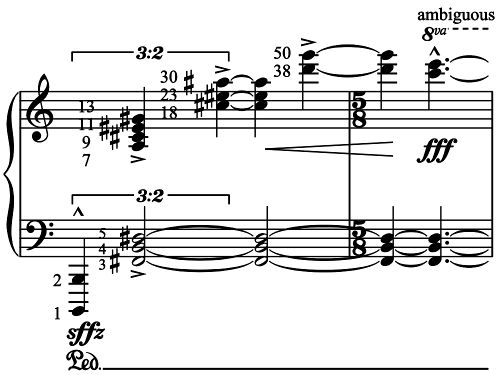

Fig.14: Golden Section aggregate

This aggregate is the only completely harmonious aggregate in this piece that contains many identity-generating lower partials. As can be seen in the above example, the fundamental is strongly emphasized (partials 1, 2, and 4), followed by four additional layers of increasing harmonic complexity. The first three layers feature partials that were commonly used for the chords in the previous section (except for partials 23 and 50) while the fourth layer introduces a tonally ambiguous high-pitched major third. These characteristics provide for a strong perceivable connection to the previous harmonic progression – in fact, this aggregate serves as its climactic end point. At the same time it does, however, stand out from the other chords due to its inherent harmonicity and the nonrecurring simultaneous use of lower partials which communicates a strong sense of "tonality". It thereby also functions as the starting point for the second macro-section of the piece which begins after the Golden Section (bar 127). Despite its harmonicity and its large number of low partials, this aggregate nevertheless sounds severely out-of-tune on a piano tuned in equal temperament (see audio example which compares versions in ET and JI).

❶, **Tr. 7**

This is mainly due to two reasons: on the one hand, there is an acoustic misrepresentation of this harmonious spectrum which contains several low partials that are inherent in many instrument spectra. As we have seen before, it is particularly the partials 7, 11, and 13 that are significantly out-of-tune (i.e. 7 is a 6^{th}-tone sharp, while 11 and 13 are even a quarter-tone sharp). On the other hand, there is the major third ´C - E ` which is ambiguous in several ways: first, the interval itself could be expressed in different manners (e.g., 67:87 or 69:85: two different major thirds between ´C` and ´E`), and second, the relation of both pitches to the actual fundamental ´B nat.` remains unclear. A further aspect contributing to the acoustic result is the overtone configuration of each pitch involved in an aggregate. All these elements, as briefly described here, lead to a harmonic-timbral tension, which lets certain pitches seem out-of-tune or certain sounds appear distorted. However, in this particular case the probability of the human ear adjusting tempered to just intervals is much higher than in any other part of the piece. This is due to the fact that several of the lower partials (i.e., 2, 7, 11, and 13) feature strongly in the low ´B nat.` of the piano. These overtones are just intervals and will therefore sound as such. When the tempered versions of these overtones are added shortly thereafter a situation arises in which the two types of intervals conflict with each other. Psycho-acoustic research suggests that the human ear then “prefers” the version with just intervals, whose constituents are whole-number multiples of their fundamental and thus part of an overall harmonic oscillation, over their tempered counterpart.[11] In addition, an educated listener who listens analytically will also be capable of recognizing the *symbolical* aspect of the aggregate which will then affect his *conscious* perception.

2.2.12 Recapitulation

The final macro-section of *LuftLinien* (bars 127-174) is in many ways analogous to the first section. In fact, it exhibits the character of a recapitulation since various ideas from previous parts of the piece are reintroduced. These include, for instance, small networks of repeated notes (e.g., bars 132, 137 and 142), and the reoccurrence of short (subharmonious) impulses and their resonances (e.g., bars 131, 150 and 158). New elements include rendering of melodic lines by taking away notes from a chord (e.g., bars 150, 160 and 174), and the use of subharmonious clusters in the bass which introduce the element of (subtle) noise and thus cause the contamination of spectra (e.g., bars 161, 168 and 172). The harmonic organization is very similar to the one at the beginning of the piece as the whole section is based on only one fundamental, i.e. ´B nat.`. Most of the spectral excerpts are inharmonious and contain high-number partials whose representation in ET renders them ambiguous with regard to their origin. Similar to the first section, the true origin of all pitches (i.e. ´B nat.`) is

[11] Manfred Spitzer, *Musik im Kopf – Hören, Musizieren, Verstehen und Erleben im neuronalen Netzwerk* (Stuttgart, 2002), 167

repeatedly re-emphasized. In this case the harmonic mapping is achieved by the reiteration of different variants of the ´B nat.`-aggregate from bars 125/126 (see, for instance, bars 139-141, 165, 167 and 172-174). At the end the ´B nat.`-"tonality" is constantly reconfirmed and the piece thus ends on the perfect fifth ´B nat. – F sharp`.

2.2.13 Conclusions

Throughout the composition process of *LuftLinien*, I carefully compared different renditions of the pitch material (i.e. JI and pitch approximations in ET) and came to realize how many elements of differentiation were inevitably lost due to the pitch simplification that ET entails. This includes the lack of microtonal pitch differentiation, the lack of multi-faceted exploration of harmonicity and inharmonicity – not only in terms of pitch combinations but also regarding its consequences for the timbre of a sound – and the inability to perceivably distinguish between chords, aggregates and the various possible intermediate steps. The representation of this type of material in ET dramatically reduces its respective degrees of complexity and meaningfulness, because the lack of intonational differentiation produces a result that is significantly more generic than the one I had in mind when I explored the potential of the harmonic material prior to the actual composition. The human ear simply cannot make up for the absence of these additional layers when it comes to the type of harmonically complex material that I used in this work. These realizations – that exact microtonal intonation not only provides differentiated and meaningful pitch contexts but also strongly influences categories such as the realization and perception of harmonicity/inharmonicity – led me to the (preliminary) conclusion that, in order to make the most of a microtonal pitch language, one would have to notate and intonate it as precisely as (humanly) possible. My extended comparative analyses of harmonies presented in both ET and JI also led to another discovery, namely, that the direct comparison of two versions of a harmonic field – once with and once without microtones – can cause a "confusion" of the ear if the two different versions are repeatedly alternated. This observation, and my subsequent experimentation with such processes, eventually led to my concept of *dynamic tone-systems*, which will be discussed later on in this thesis.

The method of retroactive (de-) contextualization of pitch material within spectral contexts has proven to be an interesting way of working with spectral material in ET as the piece invites the listener to constantly scrutinize and reevaluate the hierarchical context of pitches. I deliberately included various types of spectral situations ranging from harmonious low-partial spectra to very subharmonious structures. Working with these different degrees of spectral recognizability confirmed, that spectra containing low partials are the easiest to recognize (and remember) for the listener. Furthermore, their out-of-tune-ness in ET can be identified and corrected by "experienced" listeners. Material that is audibly spectral (i.e.

features at least some lower partials) but still complex regarding its configuration (i.e. material that includes higher partials and/or inharmonious elements as well) arguably suffers the most from an approximate realization in ET. As I explained before, it is inevitable that certain layers will be lost. As for the highly ambiguous material which, without the subsequent addition of a lower partial, would not even be perceived as spectral at all, the re-contextualization of such material leads to an interesting, if only abstract, distortion of the pitches´ identity in the listener´s mind. This way not only a “tonal hierarchy” is established through the retroactive addition of lower partials; also, factors such as the ambiguity of the material, and the fragility and flexibility of the human sense of hearing which responds to these processes in a variety of different ways, come to the fore.

My experience with this work and other pieces has shown that pitch adjustment in favour of just intonation can be achieved by the human ear under *specific conditions*. There are, however, various factors including cultural background, listening experience, general attentiveness and the willingness to listen analytically that have been emphasized by recent psycho-acoustic research about this matter, that leave me very skeptical about how specifically these adjustment processes can be executed. The experimentation with complex spectral sounds that constantly undergo processes of re-contextualization has led to an interesting perspective on pitch adjustment in equal temperament which, however, from my perspective, remains mainly abstract. In the end, it is this abstract spectral sound-world that represents the main realm of exploration for *LuftLinien*.

As a consequence of these thoughts I decided to write two short studies featuring the use of spectral material in ET in order to further explore this subject.