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Introduction to the Pitch Organization of French Spectral Music

François Rose

Introduction

Gérard Grisey (b.1946) and Tristan Murail (b. 1947) are the two best-known French "spectral" composers. Their music promotes a very specific aesthetic which gives predominance to timbre, a trend already foreseen in the stance of some institutions such as IRCAM (Institut de Recherche Coordination Acoustique et Musique) and GRM (Groupe de Recherche Musicale) and also in the works of composers like Olivier Messiaen, György Ligeti, Iannis Xenakis, and Karlheinz Stockhausen (who included consideration of timbre projected into rhythm and form in his famous article ". . . wie die Zeit vergeht . . ."). But although many composers have placed a strong emphasis on timbre, the composers of the spectral school have made it the main element in their compositions. They have also established the overtone series as their point of reference.

The overtone series is a theoretical concept which describes a set of vibrations whose frequencies are all integral multiples of one fundamental frequency (f_1). Any frequency can be used as a fundamental while the other elements of its overtone series are called respectively: the second partial (f_2) which is equal to $2 \times f_1$, the third partial (f_3) which is equal to $3 \times f_1$, and so on.

Example 1 shows an overtone series. The low E_1 (41.2 Hz) is the fundamental and it is shown with its first thirty-two partials. The microtones generated by this process are indicated with arrows and are rounded to the nearest quarter or sixth of a tone.

EXAMPLE 1: THE FIRST THIRTY-TWO PARTIALS OF AN OVERTONE SERIES BASED ON A LOW E

But the originality of spectral music does not come from the fact that it uses the overtone series. By 1850 the German physicist Hermann Helmholtz had discovered how the "color" of sound was influenced by the content and weighting of its overtone structure. Spectral music is singular and interesting because its practices respond to complex physical circumstances like the overtone series, rather than upon local and ad hoc stratagems such as are involved in building musical structures on the basis of a cell or a motif, as has been the dominant tradition in Western music.

This idea of rejecting the motif as the principal constituent element of a composition and of establishing timbre instead was posited by Grisey during a presentation at the Darmstadt courses in 1978:

> The material derives from the natural growth of sonority, from the macrostructure and not the other way round. In other words there is no basic material (no melodic cell, no complex of notes or note-values).[1]

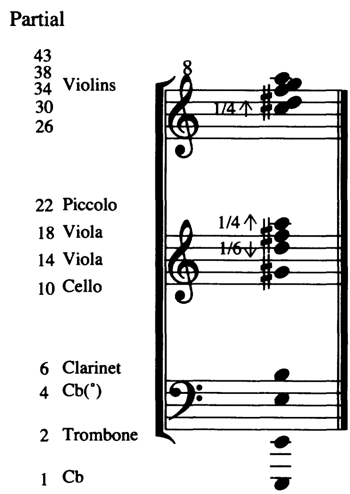
Spectral music is original, I believe, not only in its choice of models but also because of its attitude towards time. Indeed, a music based on a complex acoustic structure may be understood to require a more dilated time span. Although timbre and time are strongly linked in spectral music, time will not be discussed in this paper. (The reader interested in the temporal aspect of spectral music should read Grisey's article "Tempus ex Machina: A Composer's Reflection on Musical Time." See Bibliography.)

Harmonicity/Inharmonicity

The origin of spectral music is closely linked to the development of new technologies and more specifically to the computer, whose refinements made possible the analysis of sounds, the resolution of partials and their relative amplitudes. The basic conception of timbre used by the spectral composers is also strongly influenced by certain electronic music techniques, particularly additive synthesis. This method involves the summation of component frequencies (produced by sine tones) in order to build up complex composites.

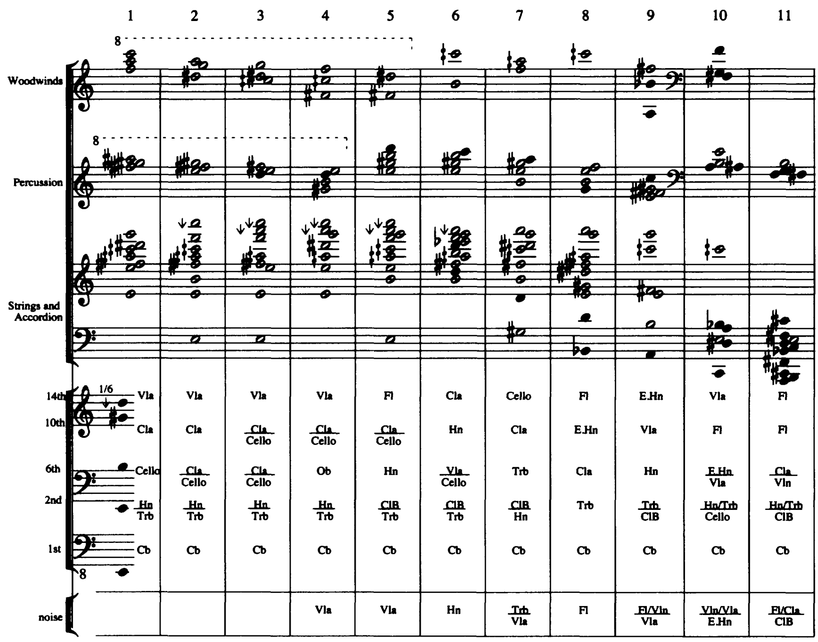
For the beginning of *Partiels* (1975), Grisey was stimulated by a sonogram analysis of a pedal low E_1 (41.2 Hz) on the trombone. He selected some component frequencies and orchestrated them. That is why this technique can be metaphorically referred to as "instrumental additive synthesis." Example 2 shows Grisey's selection of component frequencies and his assignment of them to instruments. His orchestration respects, on a larger scale, not only the frequencies themselves, but the time-point proportionality between the entrance of the model trombone sonogram's partials. It also takes into consideration the dynamic level of each component. For example, his sonogram's analysis revealed that the dynamic level of the trombone's fourth partial is low, so he orchestrated it with a natural harmonic played on the string bass, a much weaker sound than the others in the sonority.

All the frequency components illustrated in Example 2 are integral multiples of the frequency of low E: therefore this spectrum is called "harmonic." If any component is not a whole-number multiple of the fundamental, the phenomenon is called "inharmonicity." There can be varying degrees of inharmonicity. The development of the first section of *Partiels* is based on this notion.



EXAMPLE 2: THE FIRST HARMONIC STRUCTURE OF *PARTIELS*

During the course of eleven repetitions of this sonority, some inharmonic components are gradually introduced to unsettle the initial timbre. The progressive introduction of foreign components is illustrated by Example 3, where the inharmonic tones are indicated as black notes, in contrast to the white notes which indicate harmonic components. The three upper staves of Example 3 show the voicings of the woodwinds, the percussion, and the strings/accordion, respectively. Inharmonicity is achieved in stages through a downward octave shifting. For instance, Example 3 shows that the first inharmonic tone occurs in the third statement when the fifty-seventh partial of the low E (D_7 = 2348.6 Hz) is presented one octave too low (D_6 = 1174.3 Hz), by the percussion. In the sixth repetition, the fifty-first partial of the low E follows the same pattern (C_7 = 2101.5 Hz, shifted down to C_6 = 1050.8 Hz), while the octave-lowered fifty-seventh partial is lowered an additional octave, to D_5 (587.2 Hz). The same process is carried on until the eleventh statement where only two harmonic components remain, the E_3 and B_3 (the fourth and sixth partials, respectively, of the low E_1).



EXAMPLE 3: PROGRESSION FROM HARMONICITY TO INHARMONICITY IN *PARTIELS*

From the perspective of orchestration, there are some interesting points. As indicated by the three lower staves on Example 3, partials 1, 2, 6, 10, and 14 are present in each of the eleven reiterations, creating a formant-like emphasis on these partials through the entire section. At the same time, the instrumental coloration of these five constant partials is gradually modified.

Moreover, as the timbre becomes increasingly inharmonic, noise elements are added to the orchestration. The instruments which introduce the noise are indicated at the bottom of Example 3. The string instruments add noise by putting more pressure on the bow while the wind instruments achieve a similar effect by changing dynamics very rapidly while sustaining their sounds.

I have mentioned that this technique could be metaphorically referred to as instrumental additive synthesis because the analogy between the model and its realization remains theoretical. The significant difference between the model and the realization is that each component is played by a musical instrument rather than being a sine tone. In other words, the simple and anonymous oscillation of sine tones is replaced by complex sounds, each with a distinct identity. Consequently, the underlying concept of adding simple sounds together to create a complex one is modified, to the combination of several complex sounds creating an even more complex one. Thus it should be clear that the idea is not to create an acoustical reproduction of an electronic sound, but rather to adapt an electronic procedure for acoustical instruments. Naturally, the result of this procedure, while deriving from physical models, no longer shares but replaces the characteristics of the modeled phenomenon.

Microphony/Macrophony

In his piece *Transitoires* (1980–81), Grisey used sonographic analyses of a string bass, played in five different ways: pizzicato, normal, normal toward the bridge, almost on the bridge, and finally *sul ponticello*. The results of these analyses are illustrated in Example 4, and are labeled *V*, *W*, *X*, *Y*, and *Z*, respectively. Partials 1, 2, 3, 11, 13, and 15 are present in all five sounds, creating a formant-like emphasis for the entire section.

Once again Grisey incorporated the time proportionality between the entrance of the various components and also the relation between their various intensities into his orchestration. He conceived both the entire orchestra and a smaller group of instruments as two synthesized string basses, which we might call a macrophonic and a microphonic one. He further contrasted these two synthesized string basses with a real one, always presenting the three in the following order: real, microphonic, macrophonic.

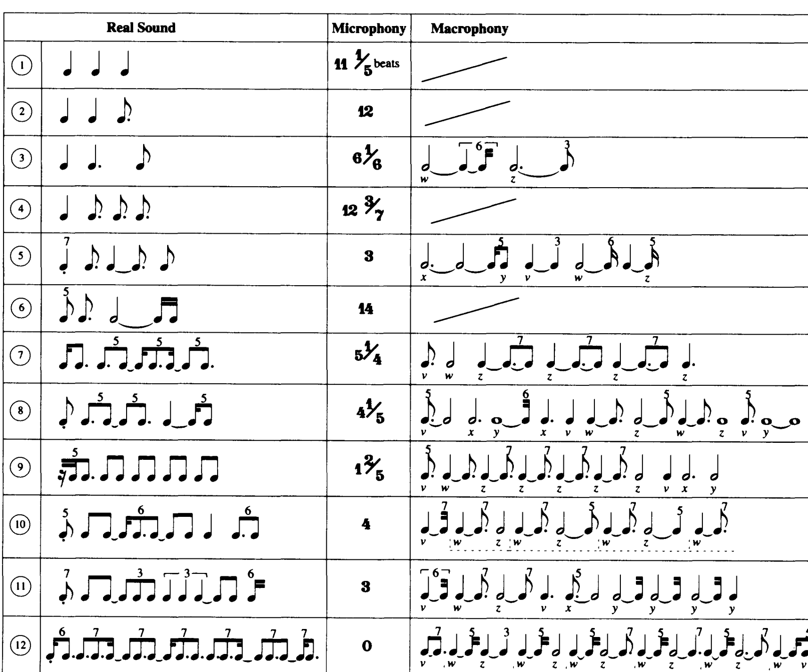
Furthermore, the succession of the three sounds imitates the amplitude contour of a real string bass sound; in this case, the real string bass mimics the attack, the microphonic one acts as the rise to the steady-state which is imitated by the macrophonic bass, as is the decay portion of the sound.

Partial number	Pizz. *V*	Ord. *W*	– *X*	– *Y*	Sul ponticello *Z*
66th					✓
55th				✓	
53rd				✓	
52nd				✓	
51st				✓	✓
50th				✓	✓
44th				✓	
37th				✓	✓
34th				✓	
33rd			✓		✓
32nd				✓	
31st			✓	✓	
30th		✓	✓	✓	
29th		✓	✓	✓	✓
28th		✓	✓		✓
27th		✓	✓	✓	✓
26th				✓	
25th			✓	✓	✓
24th				✓	
23rd			✓	✓	✓
22nd			✓	✓	
21st		✓			✓
20th			✓	✓	

Partial number	Pizz. V	Ord. W	– X	– Y	Sul ponticello Z
19th		✓	✓	✓	✓
18th			✓	✓	✓
17th	✓	✓	✓	✓	
16th			✓	✓	✓
15th	✓	✓	✓	✓	✓
14th		✓	✓	✓	✓
13th	✓	✓	✓	✓	✓
12th		✓	✓	✓	✓
11th	✓	✓	✓	✓	✓
10th		✓	✓	✓	✓
9th	✓		✓	✓	✓
7th	✓				
6th					✓
5th	✓	✓	✓		
3rd	✓	✓	✓	✓	✓
2nd	✓	✓	✓	✓	✓
1st	✓	✓	✓	✓	✓

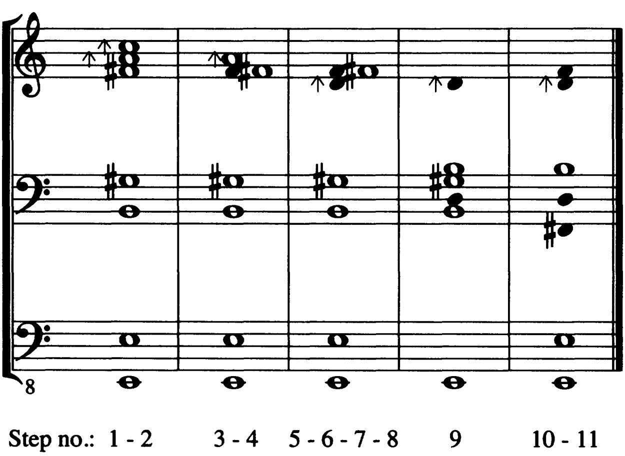
EXAMPLE 4: PARTIAL CONTENT OF THE DOUBLE BASS, ANALYZED FOR *TRANSITOIRES*

Example 5 shows the durational transformations of the three sounds; the real bass sound, its microphony, and its macrophony. The succession "real sound–microphony–macrophony" is repeated twelve times. The duration of the real bass sound gets longer and the activity within this duration gets faster. From a quarter-note periodicity the motion becomes aperiodic and then gradually returns to periodicity at a speed of $\frac{3}{7}$ of a quarter note. The duration of the microphony decreases in a sawtooth motion; it moves from $11\frac{1}{5}$ beats to 12 beats, then down to $6\frac{1}{6}$ beats then up to $12\frac{3}{7}$ then down to 3 beats and so on until it disappears completely. The process of the macrophony tends toward harmonic and rhythmic periodicity. At repetition 7, the chord *Z* is repeated three times successively at a duration of $1\frac{5}{7}$ beats. At repetition 9, it is repeated four times successively at a duration of $1\frac{3}{7}$ beats. At repetition 10 and 12, the two chords *W* and *Z* are repeated in succession and each time the duration of the *W* chord within a repetition cycle remains constant while the duration of the *Z* chord gets gradually longer. For example, in repetition 10, the duration of the *W* chord remains constant at a quarter note plus a dotted-eighth-note septuplet while the duration of the *Z* chord moves from a half-note, to a half-note plus an eighth-note quintuplet, and then to a half-note plus a quarter-note quintuplet.



EXAMPLE 5: TEMPORAL TRANSFORMATIONS OF THE REAL, MICROPHONIC, AND MACROPHONIC BASS SOUNDS IN *TRANSITOIRES*

The microphony is composed of sustained pitches which, through the twelve repetitions of the process, move in five steps from harmonicity toward inharmonicity as shown on Example 6 (where the inharmonic tones are indicated by black notes). The degree of inharmonicity is gradually increased over the five structures by the successive replacement of the harmonic components by inharmonic ones further and further away from normative positions. For example, the seventeenth partial (F_5) is displaced downward by one octave in the second structure, while the twenty-ninth partial ($D\uparrow_6$) is displaced downward by two octaves in the third one. Finally, the fourth and fifth structures add successively the fifty-seventh (D_7) and the ninth partials ($F\sharp_4$), displaced downward by four and two octaves, respectively.



EXAMPLE 6: HARMONIC PROGRESSION OF THE MICROPHONY

SUBHARMONICITY

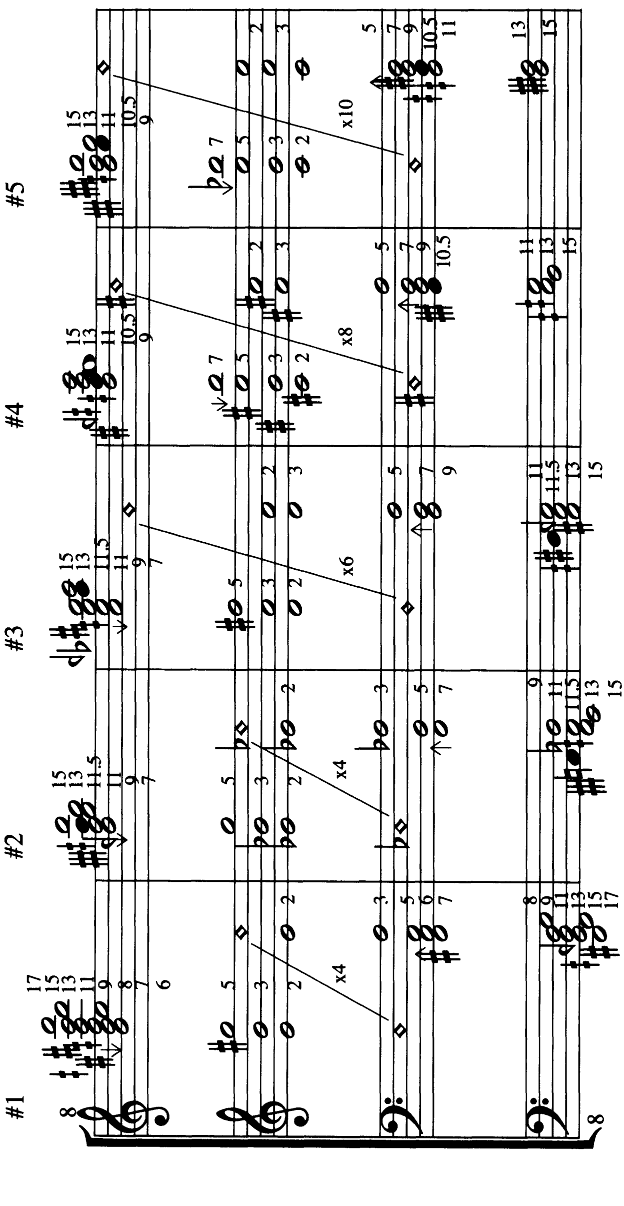
The overtone series is characterized by large intervals at the bottom which gradually become smaller and smaller in the higher register. By inverting the order of the intervals—that is, by beginning with the large intervals in the higher register—one obtains an artificial construct called a subharmonic spectrum, with a very chromatic low register. This technique is used by Grisey in *Modulations* (1976–77).

Example 7 illustrates this process. Each measure shows, on the left, a harmonic spectrum, and to its right a corresponding subharmonic spectrum. If we look at the progression of the ten harmonic spectra, we will see that:

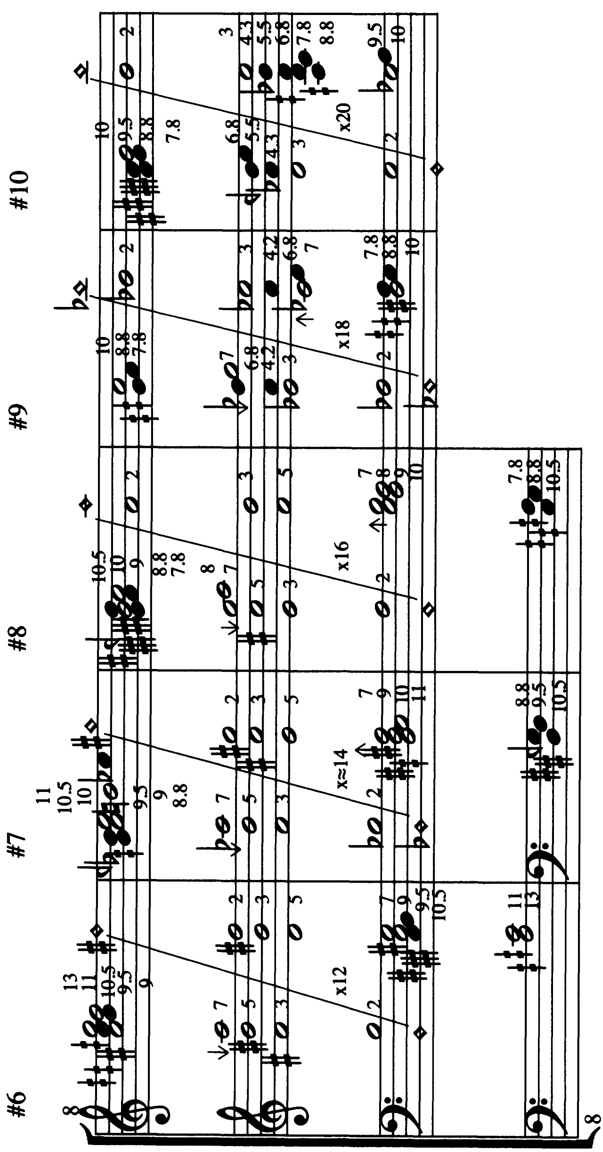
1. The fundamentals, shown as diamond-shaped notes, move chromatically from E down to G.
2. The relationship between the fundamentals of the harmonic and the subharmonic spectra rises gradually throughout this section. Over the ten steps, the fundamental of the subharmonic spectrum moves from a relationship of a fourth to the twentieth partial in relation to the fundamental of the harmonic spectrum. These relationships are shown by the straight lines in Example 7.
3. The harmonic spectra move gradually toward inharmonicity. The inharmonic components, shown as black notes, are indicated with decimals in Example 7 where "partials" 11.5, 10.5, 9.5, and 5.5 represent the twenty-third, twenty-first, nineteenth, and eleventh partials, respectively, one octave lower, and 8.8, 7.8, 6.8, and 4.3 represent the thirty-fifth, thirty-first, twenty-seventh, and seventeenth partials, respectively, two octaves lower. The tenth spectrum is decidedly inharmonic with six inharmonic components.
4. The spectra get gradually more and more compressed. Though all have a substantial number of components, in the first harmonic spectrum they lie between its second and seventeenth partial while in the tenth one they are between its second and the tenth partial.
5. There is a gradual design to bring the harmonic and subharmonic spectra closer together. For example, while the first harmonic spectrum covers the high register the subharmonic one covers the low register. The only pitch they have in common is the E_4, but in the tenth and last chord, the second and tenth components of the harmonic spectrum are equal to the tenth and second components, respectively, of the subspectrum.

Filtering Technique

The composers of spectral music have been influenced by several electronic processes besides additive synthesis: filtering, ring modulation, and frequency modulation among others. The conceptual behavior of each process is metaphorically transposed from the electronic domain to the acoustical one.

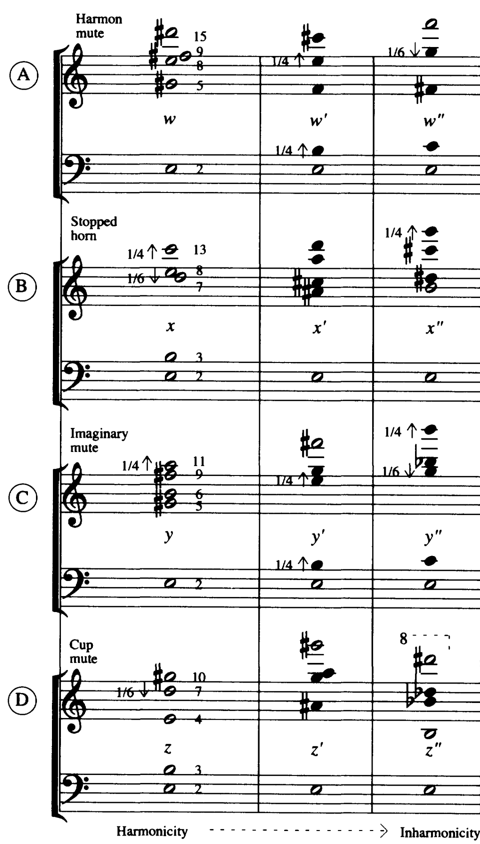


EXAMPLE 7: SUBHARMONICITY IN *MODULATIONS*



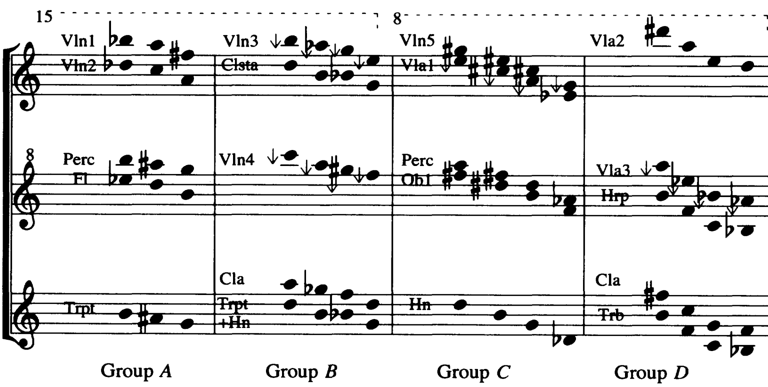
EXAMPLE 7 (CONT.)

Spectral analyses have shown that mutes behave as filters. They inhibit some spectral areas while enhancing some others. Having analyzed the spectral influence of different mutes on a low E_2 on the trombone, Grisey used his results to produce an impressive timbral transformation in *Modulations* (1976–77). As shown in Example 8, the ensemble is divided into four groups labeled *A*, *B*, *C*, and *D*, with an overall harmonic progression from harmonicity toward inharmonicity. The harmonic content of each group is based on his analyses of the different mutes. For example, his analyses revealed that partials 2, 5, 8, 9, and 15 of the low E were enhanced when this fundamental was played on a trombone muted with a Harmon mute. Consequently, Grisey specifically chose the pitches corresponding to those partials to define the voicing of Group *A*. He used the same procedure for Group *B* (stopped horn), Group *C* (an imaginary mute), and Group *D* (cup mute).



EXAMPLE 8: VOICING BASED ON ANALYSES OF THE TROMBONE'S MUTES

The first collection of chords used by each group is illustrated in Example 9. As indicated, the specific voicing of each group is transposed over the descending lower voice. Because those four groups are presented in succession, Grisey thinks of this procedure as a counterpoint of different timbres. He refers to this idea as a *spectral polyphony.* The techniques of interpolation used to join chord w to w' and then to chord w'' will be presented later.



Vln 3 is tuned a quarter tone flat
Vln 4 is tuned a sixth tone flat
Vln 5 is tuned a quarter tone flat
Vla 3 is tuned a sixth tone flat

EXAMPLE 9: FILTERING TECHNIQUES IN *MODULATIONS*

Combination Tones

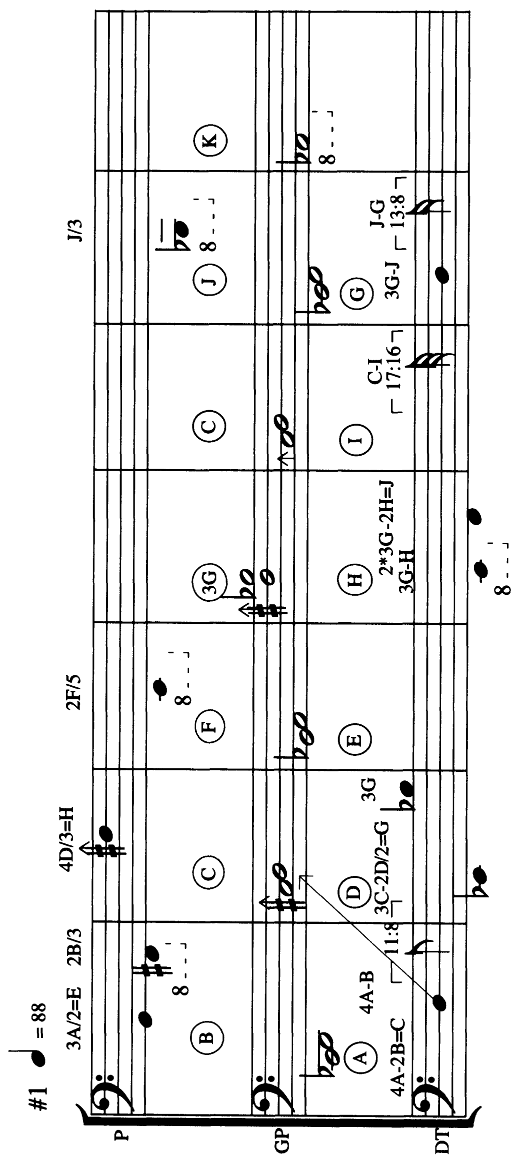
This technique is the acoustical counterpart to ring modulation. The combination tones between any two frequencies A and B are obtained by adding and subtracting the two frequencies: $A + B$ gives the summation tone while $A - B$ gives the difference tone. This principle can be extended to infinity if we consider second-order, third-order, (et cetera) combination tones. In the case of second-order combination tones, the summation and difference tones are taken between all the pairings involving the second-harmonic components, both with each other and with the fundamental frequencies (i.e., $2A + 2B$; $2A + A$, $2A - A$, $2A + B$, $2A - B$; $2B + B$, $2B - B$, $2B + A$, $2B - A$; $2A + 2B$ and $2A - 2B$).

Grisey thinks of combination products as "shadow-tones." He has used this technique in several pieces, including *Partiels* and *Modulations*. Example 10 shows the use of this technique in *Partiels*.

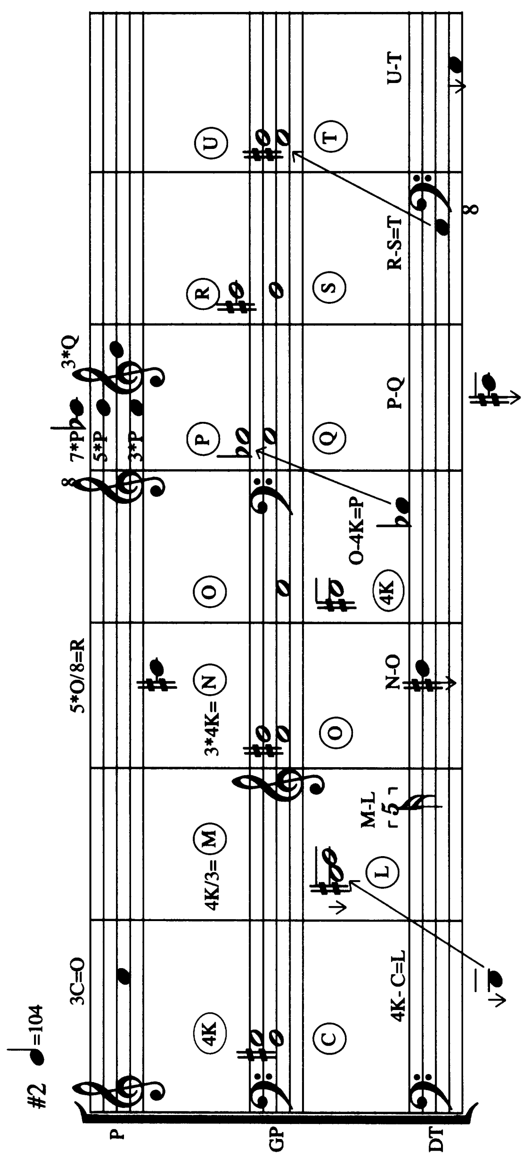
Four observations can be made about the overall progression:

1. In Example 10, the three-stave system shows from top to bottom: the partials, the generative pitches, and the difference tones. The generative pitches are labelled with circled letters, which are used to show how the difference tones were calculated and the harmonic relationship between the generative pitches and the partials. For instance, in the first measure of Example 10, the low C_2 (65.41 Hz) and the $D\flat_2$ (69.3 Hz) a semitone higher are two generative pitches labeled *A* and *B*, respectively. The pitch D_3 (146.38 Hz) is a fourth-order difference tone between the two generative pitches since $(4 \times 69.3) - (2 \times 65.41) = 146.38$. Consequently, the shadow-tone D_3 is labeled *C* and this letter is preceded by the formula $4B - 2A$. On the other hand, G_2 (98 Hz) and $F\sharp_1$ (46.24 Hz) are harmonically related to C_2 and $D\flat_2$ (enharmonic for $C\sharp_2$), respectively. The generative pitch C and the shadow-tone G are the second and third partials of a low C_1 (32.7 Hz), while the generative pitch D♭ and the shadow-tone F♯ are the third and second partials, respectively, of a very low $F\sharp_0$ (23.12 Hz).
2. The generative pitches move in an oscillating motion from the low to the high register as indicated in Example 11. The ratio between the frequencies of the two generative pitches provides important information about the degree of harmonicity of their shadow tones. A simple ratio ensures that the shadow tones will be in a harmonic relationship with the two generative pitches, while a complex ratio gives an inharmonic relationship.

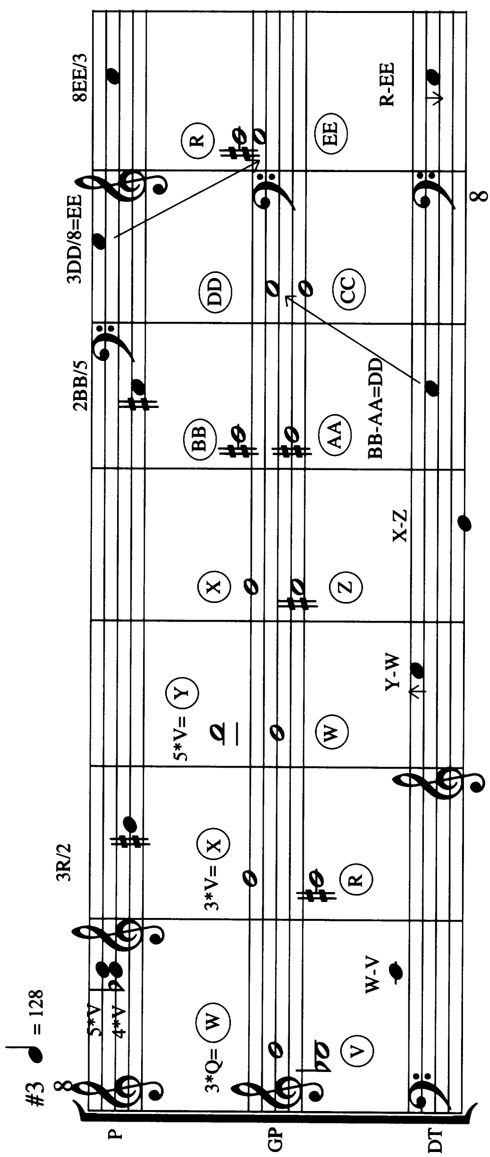
   As shown in Example 11, the main intervals between the two generative pitches are tritones and seconds (major or minor, including seventh and ninth). Those intervals produce inharmonic results. But in the third measure of the last system of Example 10 or, equivalently, the third dyad of the fifth (last) group in Example 11, there is a decisive change of relationship between the two generative pitches: $G\sharp_5$ and E_6 correspond to the fortieth and sixty-fourth partials, respectively, of a low E_1 (41.2 Hz), as indicated by the numbers in the square boxes. Consequently, all the combination tones produced by those two generative pitches are partials of the low E_1.



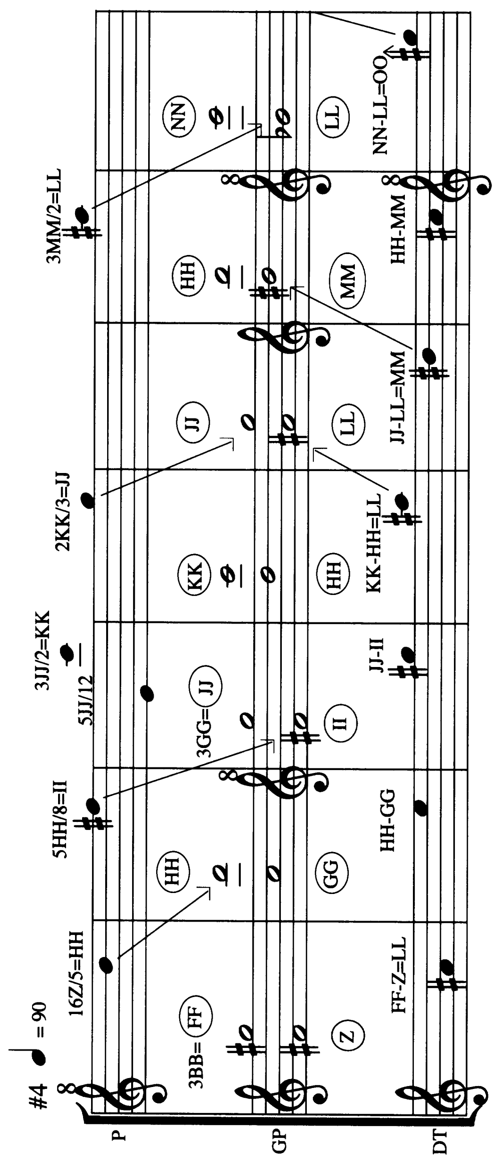
EXAMPLE 10: COMBINATION TONES IN *PARTIELS*



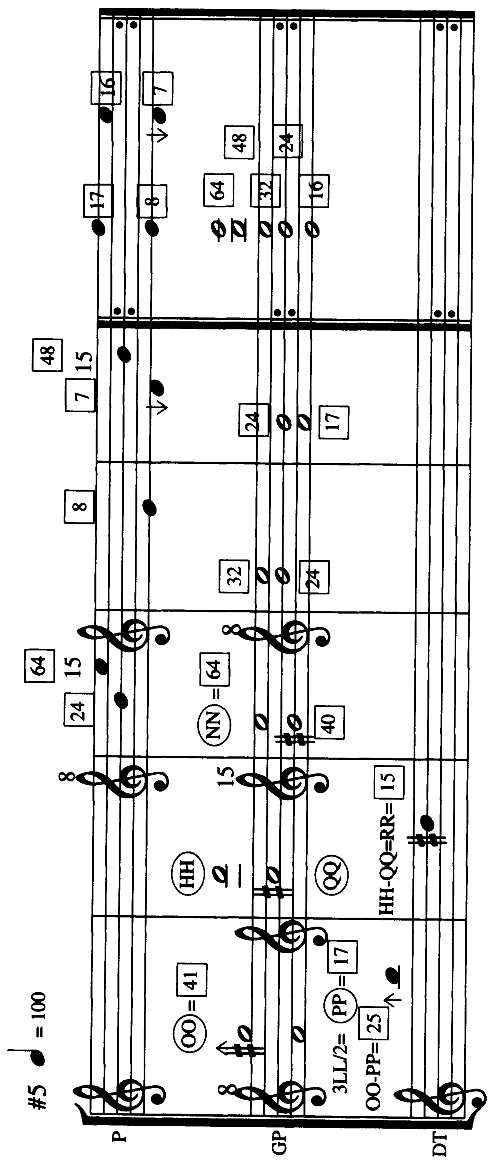
EXAMPLE 10 (CONT.)



EXAMPLE 10 (CONT.)

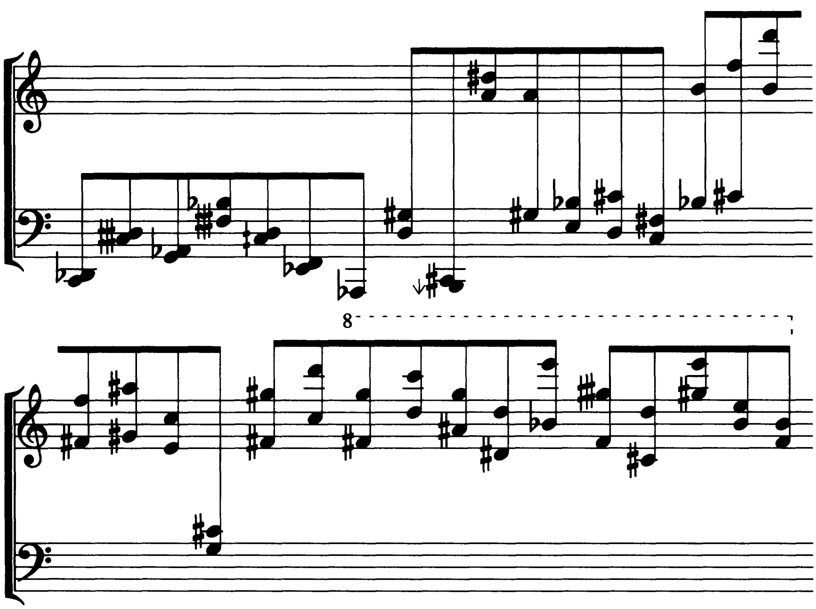


EXAMPLE 10 (CONT.)



EXAMPLE 10 (CONT.)

For example, in the third measure of the last system the twenty-fourth partial of the low E, the B_5 (987.8 Hz) is also the first-order difference tone between the sixty-fourth and fortieth partials ($64 - 40 = 24$). This change of relationship between the two generative pitches is anticipated earlier in the second, third, and sixth measures of the third system and in the fifth measure of the fourth system, with a major third, minor tenth, minor sixth, and a major sixth, respectively, all of which produce harmonic results (these correspond in Example 11 to the second, third, and sixth dyads of the third group and the fifth dyad of the fourth group, respectively).



EXAMPLE 11: PROGRESSION OF THE GENERATIVE PITCHES

3. The change from inharmonicity to harmonicity is also prepared through control of the number of pitches generated in each section. The arrows in Example 10 show that the introduction of new pitches is gradually reduced since partials and difference tones are increasingly used as generative pitches in subsequent sections.

While only one shadow tone is used as the next generative pitch in the first presentation of the process (first system), eight are so used in the fourth repetition (fourth system). At that point the shadow-tones and generative pitches are all focusing toward the harmonic spectrum of E.

4. The combination-tone technique is not used solely to generate harmonic components. As indicated in the first measure of Example 10, the difference tone between the two generative pitches C_2 (65.41 Hz) and $D\flat_2$ (69.3 Hz) produces a rhythmic pulsation since 69.3 Hz – 65.41 Hz = 3.89 Hz. A frequency of 3.89 Hz has a period of 1/3.89 = 0.26 second. At this point in the piece, the tempo is MM = 88, at which speed a beat lasts 0.682 second. Consequently, a period of 0.26 is approximately equal to that of eleven pulsations in the time of four beats at MM = 88 (0.682 ÷ 0.26 = 2.62). But as the generative pitches move from the low to the high register, the shadow-tones move from rhythmic pulsation to audible pitch. While three pulsations are generated in the first presentation of the process (first system) a final one is produced in the second presentation (second system). Thus, harmony, timbre, and this facet of rhythm are different types of results, all generated by the same process.

Another interesting aspect of this section of the piece is the strong correlation between the vertical and horizontal organization of the composition: the transformation over time of the timbral harmonies and their durations, respectively. A time matrix of 42.5 beats (twenty 2/4 measures plus one 5/8 measure) is used to control the generative pitches' entrances at first. This time matrix is repeated three times, first at MM = 88, then at MM = 104, and the third time at MM = 128. Consequently, while the number of beats of the time matrix remains stable, its total duration is shortened through the manipulation of metronome markings.

For the fourth repetition, the time matrix is reduced to half its size (twenty-one beats) at MM = 90. And finally for the fifth repetition, it is shortened even more, to fifteen beats at MM = 100. As shown in Example 11, seven pairs of generative pitches are presented in the first four repetitions of the process, and only six in the last one.

The progression of durations is summarized in Example 12. The duration of each of the seven entrances of the set of generative pitches is indicated in number of beats. In the first step the seven durations are totally aperiodic while in the fifth one they oscillate slightly around 2.5 beats (at MM = 100 this equals 1.5 seconds). Finally, the section reaches a point of cadence where the changes occur periodically every 1.5 seconds. (This cadential point corresponds to the last measure in Example 10).

				Duration in beats of the seven changes						
				1	2	3	4	5	6	7
MM	Number of beats	Duration in seconds	Number of changes							
= 88	42.5	29	7	9	4.5	5.5	3	4	6.5	11
= 104	42.5	24.5	7	7	9.5	3.5	4	5.5	4.5	9.5
= 128	42.5	20	7	8	5.5	4	5	4.5	6.5	9
= 90	21	14	7	4.25	1.75	3.25	2.25	2.5	3	2
= 100	15	9	6	2.5	2.75	2.25	2.5	2.75	2.25	

EXAMPLE 12: TRANSFORMATION OF THE DURATIONS

In conclusion, vertical and horizontal organization—expressed as harmony and rhythm—follow parallel processes, since the harmonic motion (inharmonicity toward harmonicity) is imitated in the temporal domain by the motion of aperiodicity toward periodicity.

Furthermore, it has been demonstrated that, due to Grisey's control of both the intervals between the generative pitches and the rate of introduction of new pitches, the harmonic motion from inharmonicity toward harmonicity is made very gradual. This gradual motion is also reflected in the temporal domain, except that here it is the number of beats between the shortest and the longest durations within a single repetition which is gradually reduced. In the first step of the process, the longest and shortest durations are eleven and three beats, respectively, with a difference of eight beats between them. This difference is reduced to 6 beats (9.5 – 3.5) in the second step, to 5 (9 – 4) in the third one, and to 2.5 (4.25 – 1.75) in the fourth step, before reaching near-periodicity in the fifth step where the difference has been reduced to 0.5 beats (2.75 – 2.25).

Frequency Modulation

John Chowning's concept of frequency modulation (FM) is straightforward: a spectrum is created through the modulation between two frequencies. The carrier frequency, *c*, is altered by the modulating one, *m*, while the number of partials in the resulting spectrum is determined by an index of modulation, *i*. As indicated by the following basic equation, the frequencies present in an FM spectrum are all summation and difference tones between the carrier and modulating frequencies:

$$F_i = |c \pm (m \cdot i)|$$

The ratio m/c shows the degree of harmonicity of the resulting timbre. Simple ratios such as 1/2, 2/3, 3/4 create harmonic spectra, while complex ratios produce inharmonic ones. (The reader interested in FM should look at Chowning's article, "The Synthesis of Complex Audio Spectra by Means of Frequency Modulation." From this it will be apparent that the equation provided here is a simplification of Chowning's equation: for reasons of simplicity the part of the equation related to amplitude has been left out).

Tristan Murail used FM technique as a metaphor in generating the harmonic structures in the first section of his piece *Gondwana* (1980) for orchestra. He used G_4 (392 Hz) as a carrier and $G\sharp_3$ (207.65 Hz) as the modulating frequency, and chose 9 for the index of modulation. Example 13 shows the summation and difference tones resulting from the preceding formula.

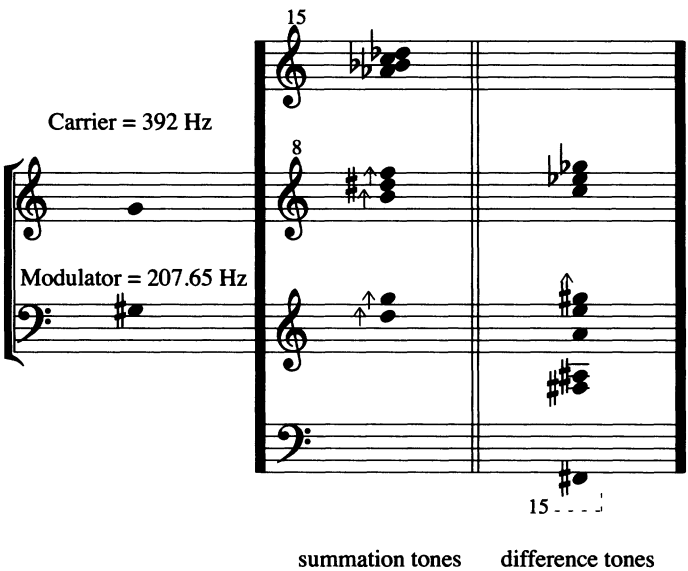
Summation tones	*Difference tones*
St1 = 599.65 Hz (D↑)	Dt1 = 184.34 Hz (F♯)
St2 = 807.3 Hz (G↑)	Dt2 = 23.3093 Hz (F♯)
St3 = 1014.95 Hz (B↑)	Dt3 = 230.96 Hz (A♯)
St4 = 1222.6 Hz (D♯)	Dt4 = 438.61 Hz (A)
St5 = 1430.26 Hz (F↑)	Dt5 = 646.27 (E)
St6 = 1637.91 Hz (A♭)	Dt6 = 853.92 Hz (G♯↑)
St7 = 1845.56 Hz (B♭)	Dt7 = 1061.57 Hz (C)
St8 = 2053.21 Hz (C)	Dt8 = 1269.22 Hz (E♭)
St9 = 2260.87 Hz (D♭)	Dt9 = 1476.88 Hz (G♭)

(↑ = 1/4tone higher)

EXAMPLE 13: SUMMATION AND DIFFERENCE TONES CALCULATED WITH THE FM FORMULA

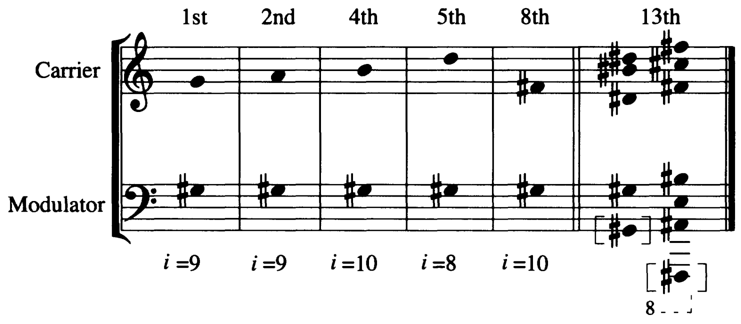
Murail rounds most of the tones to the twelve-equal-tempered scale, except where pitches fall almost exactly on a quarter tone. These are indicated in Example 13 with arrows.

Murail combined the summation and difference tones to build the harmonic structure which begins *Gondwana*. The result is shown in Example 14.



EXAMPLE 14: FREQUENCY MODULATION IN *GONDWANA*

Since the ratio m/c equals approximately 17/32, the spectrum is rather inharmonic. While Example 15 shows the carriers and modulators that Murail used to generate his first, second, fourth, fifth, and eighth sound structures, Example 16 shows only the pitches he included in his orchestration. The thirteenth structure, used at the beginning of the second section of the piece, is made of the superposition of two harmonic spectra, one based on $G\sharp_2$ (103.83 Hz) and the other one on $F\sharp_0$ (23.1 Hz)—the fundamentals themselves, however, are not present. (The composite technique he used to generate the other chords is the topic of the next section.) Example 16 shows the entire progression.



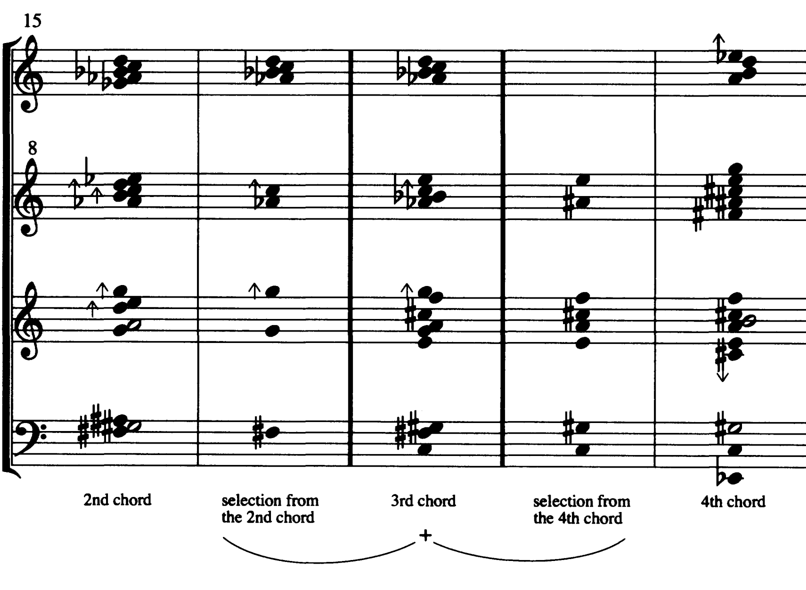
EXAMPLE 15: THE CARRIERS USED BY MURAIL FOR *GONDWANA*, FIRST, SECOND, FOURTH, FIFTH, EIGHTH, AND THIRTEENTH SOUND STRUCTURES

A very important component of Murail's musical language is his orchestration technique. A description of the orchestration of *Gondwana*'s first chord will help to illustrate this point. Murail gave the first chord a bell-like orchestral envelope with the medium-low frequencies played by the brasses including the modulator which is played by the tuba. The high frequencies are played by the woodwinds but in an unfamiliar distribution. The first clarinet in E♭ plays an A$\flat_6$ (two octaves above the second-space A♭ in treble clef) while the two first oboes play $F\uparrow_6$ and $E\flat_6$ respectively. The clarinet's pitch, being in a more comfortable register than the two oboes, is spectrally richer, its sound more present. This way Murail imitates a common phenomenon found in most acoustical sounds including bells, where some frequencies resonate more strongly than others. Moreover, the fast fade-out of higher partials which characterizes bell sounds is imitated by an instrumental transfer. Basically, instruments which have a timbre rich in higher partials, such as trumpets and horn, are faded out and replaced by three clarinets, which have a timbre less rich in higher partials. Murail also uses the piano, vibraphone, two crotales, and two tubular bells to evoke the attack of the bell sound. Moreover, the pitch material of these instruments includes several equal-tempered approximations of the microtones played by some other instruments of the orchestra, thereby producing microtonal friction which creates beating, an effect reminiscent of the bell. Thereby, the orchestration which is integrated in the musical language is as important as all the other compositional components. Timbre is brought to the foreground of the organizational dimension.

EXAMPLE 16: HARMONIC PROGRESSION FOR *GONDWANA*'S FIRST SECTION

TECHNIQUES OF INTERPOLATION

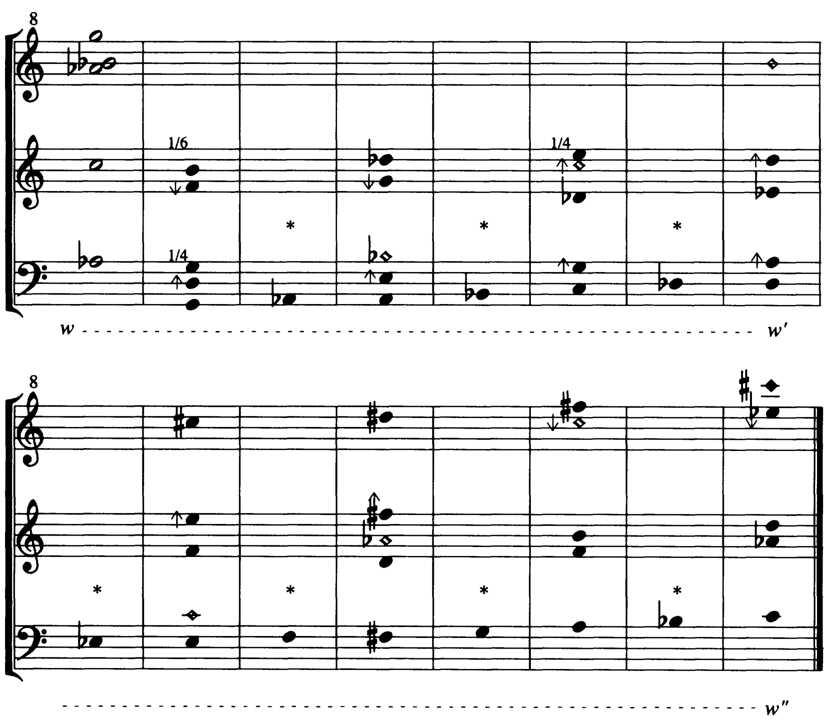
Grisey and Murail have both used certain procedures to generate intermediate steps between points defined by the procedures discussed thus far. As was mentioned before, Murail uses twelve chords in the opening section of *Gondwana*, the first, second, fourth, fifth and eighth chords calculated with the FM formula, while the thirteenth one is created by the superposition of two harmonic spectra. Each of the intermediate chords is a composite of the two adjacent chords. For example, the third chord is made of a combination of some elements of the second and fourth chords, as shown in Example 17.



EXAMPLE 17: TECHNIQUES USED BY MURAIL TO GENERATE INTERMEDIATE STEPS IN *GONDWANA*

It is also interesting to notice that we find in the first section of *Gondwana* an example of interpolation of orchestral envelope (by "orchestral envelope" I metaphorically refer to the overall shape produced by the evolution of the registral scope of an orchestral sound). The first harmonic structure described above is given a bell-like envelope, while the twelfth one is given a trumpet-like envelope. The gradual transformation from the first envelope to the twelfth produces ten intermediate orchestral shapes that Murail uses to determine the entrance and cut-off time points for the different registers of his orchestral masses.

Grisey uses a different approach to interpolation in *Modulations.* I have shown in Example 8 that the orchestra is divided into four groups. Each group starts with a harmonic spectrum and moves in two steps toward an inharmonic spectrum. Example 18 shows how Grisey interpolates the intermediate harmonic steps.



The * indicates that the harmony over the bass note is exactly the same as the preceding chord, but transposed a semi-tone higher.

EXAMPLE 18: TECHNIQUE OF HARMONIC INTERPOLATION USED BY GRISEY IN *MODULATIONS*

At this point, group *A* is orchestrated with the initial voicing of group *D* (with the exception that the lower fifth is a quarter tone sharper) using

G_2 (98 Hz) as a fundamental. The fundamental moves up a fifth chromatically while the chord structure is gradually transformed. First, the third component of the chord moves from an octave relationship with the fundamental to a minor ninth, then the fourth component moves from a quarter-tone flat minor seventh to a quarter-tone sharp octave, and finally the fifth component moves from a major third to a major sixth to produce the w' structure. The altered components are indicated with diamond-shaped notes in Example 18. A similar process is repeated until the w'' structure is reached.

Example 18 shows only the process for group *A*, but the same principle applies to the three other groups with the following changes; group *B* is orchestrated with the initial voicing of group *C* based on $A\flat_2$ (103.83 Hz), group *C* is orchestrated with the initial voicing of group *B* based on A_2 (110 Hz) and finally group *D* is orchestrated with the initial voicing of group *A* based on $B\flat_2$ (116.54 Hz).

Conclusion

The first and most important concept proposed by spectral composers is the rejection of the successive interval relationship as the principal constituent element of a composition and the establishment of timbre instead. Moreover, concepts like harmonicity, inharmonicity, and subharmonicity lead to a special definition of harmonic language in this music; essentially, harmony and timbre become two different facets of the same phenomenon. In combination with the use of interpolation strategies, spectral music offers a new sense of harmonic direction based on structural parallelisms without the use of a hierarchical system.

But the contribution of spectral music is not exclusively to be found in its rationale for chordal identity and succession. With its transference of such phenomena as ring modulation, frequency modulation, combination tones, and filtering from the electronic to the acoustical domain, it presents new compositional ideas and generates new procedures like microphony and macrophony.

Although spectral music has often been criticized as restricting the individual character of melody, polyphony, and rhythm in the name of fusion and continuity, it is indisputable that the strength of the concepts and ideas derived from spectral music are unique. As a result, it puts listeners in the position of having to find new ways of listening to and understanding music. Could a polyphony between two voices, lasting fifteen seconds, be transformed into a polyphony between two timbres lasting five minutes?

Spectral practices have succeeded in making one think in new terms. They propose to make one feel new kinds of musical time and to bring timbre into the composer's palette on the same level as melody, harmony, or even form.

A Recommendation

Although this article focuses on the two best known French "spectral" composers Gérard Grisey and Tristan Murail, the reader interested in investigating this subject further should also look at the music of, among others, Hugues Dufourt, Kaija Saariaho, Horatiu Radulescu, and Mesias Maiguashca.

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Notes

1. Record notes; Gérard Grisey, Erato STU71157, 1981.

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