Chapter 1

AN INTRODUCTION TO SPECTRAL MUSIC

In the early 1970s, a group of young French composers[1] was writing pieces starkly different from the music of most of their contemporaries. The music of the young French composers was based on slow harmonic development, and was devoid of a prominent melody or a strong sense of pulse. The music was not, however, lacking in either focus or coherence. These composers were interested in the developing field of computer music as well as in acoustical research, and their music reflected these interests. In general, they were greatly interested in the fundamental nature of sound, in particular, the overtone series. Rather than creating works based on chord progressions or tone rows, these composers wrote pieces that were constructed on the development of a sound spectrum,[2] working with harmonic spectra. Many of the ideas utilized by these composers were inspired by electronic music (especially its technology), leading the young French composers to rich and exotic sounds. Instead of writing works based predominantly on pitch relationships (tonal or otherwise), these composers were writing music that was focused on the sonorous nature of music.

By the late 1970s, there was a large enough body of works that writers attempted to codify the music. Hugues Dufourt gave the emerging style a name when wrote an article in

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[1] These composers include Tristan Murail, Gérard Grisey, Hugues Dufourt, Michael Levinas, and Mesias Maiguashca, according to Viviana Moscovich, "French Spectral Music: an Introduction" Tempo 200 (April, 1997):21.

[2] A sound spectrum is a time-varying analysis of a sonic event. Most often, the sonic event is a musical instrument playing a note. The analysis will reveal the presence or absence of partials in the harmonic series. Each partial will have a unique presence in the sound, which is what gives the sound its characteristic. See Appendix I for a reproduction of the harmonic series.

1979 entitled "Spectral Music." He spoke of the tendency of the music to focus on the microstructure of sound, the ever-changing relationships between the pitches of a sound's overtone structure as it develops in time.[3] Dufourt and many other writers observed that spectral music is based on the development of a spectrum, or a group of spectra. Since the spectra are in a constant state of evolution, the spectra can potentially have an impact on harmonic motion. The spectra can also influence orchestration, as the relative amplitudes of certain instruments might well reflect the relative amplitudes of the pitches in a particular overtone series.[4] For example, the orchestration conceivably could have a particular sonority appropriate the characteristics of a low piano note. Moreover, if that harmonic series were based on an electronic modification of a sound, the results might be quite unusual.

Various writers have remarked how spectral music eschews traditional melody and counterpoint. The musical surface of a typical spectral work does reveal occasional fragments of melody, but the main focus is the overall timbre. Moscovich suggested that the spectrum 'replaces' the elements of "harmony, melody, rhythm, orchestration, and form."[5] 'Replace' may be an inappropriate word for the result of spectral processes and conception. Composer Tristan Murail speaks of the fusion of harmony and timbre into a single sound-object, which becomes the basis for his music.[6] Dufort's description of spectral music mentioned the constant evolution of a sound's spectrum; if a spectral composer were to reproduce this effect, harmony and timbre would be in constant motion. It would even be possible to create rhythmic structures based on the durations of selected partials. The shape of a work, then, might be generated by the protracted evolution of a

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[3] Peter Szendy, "Spectra and Spectres et musique spectrale," [Spectres and spectral music], in "L'identité du son: Notes croisées sur Jonathan Harvey et Gérard Grisey" by Makis Solomos [Identity of the sound: crossed notes on Jonathan Harvey and Gérard Grisey], *Résonance* 13 (March 1998): [Internet, WWW]. ADDRESS: <http://mediatheque.ircam.fr/textes/Solomos98a>.

[4] Moscovich, 22.

[5] Moscovich, 22.

[6] Tristan Murail, "Spectra and Pixies," trans. Tod Machover. *Contemporary Music Review* 1 (1984): 158.

single sound, thereby making it possible for spectral processes to influence the musical elements of harmony, melody, rhythm, orchestration, and form.

What are spectral processes? In practice, the processes have involved transformation from one spectrum to another. A spectrum is quite often produced from an analysis of a particular note played on a specific instrument, often with particular characteristics (for example, muted, played on an open string, and a *sforzando* attack). The composers often choose to modulate, by any number of means, to a different spectrum. The second spectrum may be from a different instrumental source, or it may be an electronically-produced sound. Furthermore, the new spectrum could contain a more "dissonant" timbre if the spectrum is unrelated to a harmonic series.[7] The composer is able to produce different types of spectra, some of which sound more "dissonant" to him, while others sound more "consonant." The inclusion of relatively "consonant" and "dissonant" harmonies enables the composer to create a syntax utilizing them as contrasting states of tension. Therefore, the spectral processes can produce a motion from harmonic stasis to perturbation to stasis. The harmonic motion in spectral music has the potential to replicate the tension-release paradigm that has been the basis for Western music for centuries.

Spectral music differs from much traditional music, even from most twentieth century music. Often a single sonority is present for an entire section of music frequently lasting several minutes. Since the harmonic units unfold very slowly, the listener becomes aware that the sonority is quite important. Changes in harmony become easily recognizable. Spectral composers do not make use of functional harmonic progressions the way tonal composers do; instead, the harmonies are often metamorphosed from one to the next. [8]

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[7] See Appendix I for a reproduction of the harmonic series. A spectrum that is closely related to the harmonic series may be perceived as consonant. Conversely, a spectrum that varies greatly from the harmonic series is usually perceived as dissonant or noisy. For instance, the spectrum of a cymbal contains many frequencies, not at all resembling the harmonic series.

[8] For an example of harmonic metamorphosis, see the discussion on the first section of *Désintégrations* in Chapter 2. During the first section, two chords are slowly transformed into a third chord that is a

Does the lack of functional harmonic progression and thematic (or motivic) material prevent the listener from clearly understanding the musical intentions of a spectral composer? No, because the spectral composers often utilize musical gestures that reflect the harmonic characteristics. As in tonal music, the tension and release paradigm has a strong influence on the spectral work. If a harmonic unit is discordant (that is, not directly related to the overtone series), the resulting section of music could sound agitated. Other musical elements may be applied that would highlight the musical disturbance, such as the use of non-pitched percussion or extended instrumental techniques. The result would be a passage charged with excitement and tension. The listener might perceive the section as one moving towards a climax.[9]

Therefore, the lack of 'themes' or even 'motives' should not hinder the listener's ability to decipher the spectral composer's intentions. Instead of employing themes or motives, the spectral composer creates harmonies with the use of *timbre-chords.*[10] The timbre-chords provide the basic building blocks for the work, and one may hear a spectral work as a gradual transformation of these sound masses. As in previous music, there are points of arrival, climax, and cadence. How these points are achieved in spectral music is unique to the musical style, but they are clearly present on the musical surface.[11] The connection with music of the past is important. Despite the originality of the musical materials, all of the composers involved with the early development of spectral music were well versed in the music of the past. These composers learned a great deal from the music

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combination of both chords. Examples 2-1a and 2-1b are a reduction of the beginning and end of the passage. See the accompanying discussion for a description of the entire process.

[9] See, for instance, the discussion on Section III of *Désintégrations*, where the surface material is varied to enhance the motion towards the climax.

[10] In spectral music, timbre and harmony are often fused into a single element. This is not to be confused with Erickson's concept of timbral fusion (see Robert Erickson, *Sound Structure in Music*, (Berkeley, Los Angeles, London: University of California Press, 1975) 46-57. In Erickson's theory, diverse timbres will fuse into a composite sound when played together. A timbre-chord is a harmonic unit that is orchestrated in a particular way, regardless of whether the chord is struck simultaneously. If the timbre-chord is re-orchestrated, the timbre is changed, and a spectral composer treats it as a significant departure from the original.

of the twentieth century, and their own musical concepts are clearly bound in earlier music. They absorbed certain features and tendencies and not others. The musical syntax of formal articulations (arrivals, climaxes, and cadences) has always been present in their music. However, the fundamental nature of the musical materials changed. Spectral composers were fascinated with timbre. Gradually, timbre eclipsed melody as a primary musical element.

The gradual emergence of the notion of timbre as a compositional determinant can be traced from the mid-19th Century to more recent times. Timbre gained greater musical significance with the music of Debussy and Varèse and grew more prominent in the works of Ligeti and Scelsi.

The remainder of this chapter will focus on the historical influences on spectral music. Specifically, the focus will be the historic development of composers' ideas about timbre. The first section will concentrate on the musical developments that gave rise to the prominence of timbre. The second section will demonstrate the influence of technology on spectral music. A final section will discuss other influences on spectral music.

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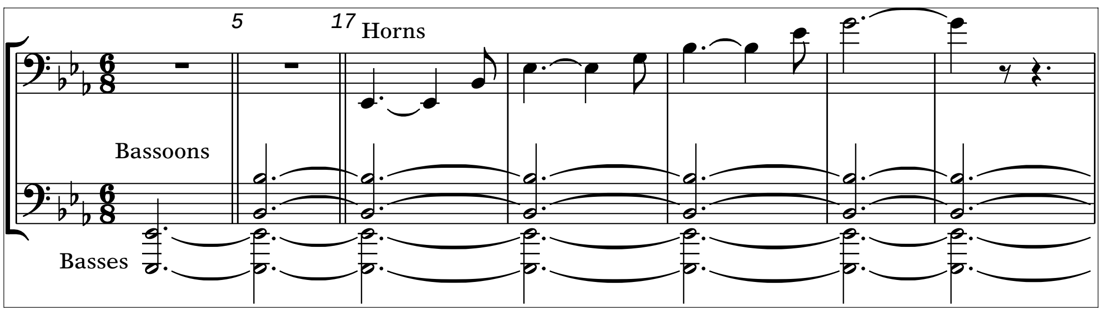
[11] There is an interesting parallel between the slow and gradual harmonic motion found in spectral music and the motion found in minimalist music.

Part One: Historic Influences on Spectral Music or a Mini-history of timbre

It is possible to trace the precursors of spectral music from nineteenth-century pieces (or specific passages) that focus sharply on timbral evolution. Marc-André Dalbavie has pointed to the *Prelude* of Wagner's *Das Rheingold* as an early example of timbral evolution.[12] The low E♭1[13] is sustained in the contrabasses while the bassoons and horns play the overtones over the low E♭1. See Example 1-1.



Example 1-1 *Das Rhiengold, Prelude*. Reduction of measures 1-21. Note that the phrase starting in measure 17 is repeated canonically by the horns in the measures following this example.

Although the *Rhiengold Prelude* is not a work focused on timbre, it uses the overtone series to create a musical structure using the E♭ as a pedal. In the Prelude, all the motifs are generated by the gradual unfolding of the E♭'s overtone series. The horns are quite capable of generating the harmonic series, and Wagner's choice of instrumentation here suggests a natural horn. The motive begun in measure 17, a rising arpeggio, is soon imitated in the other instruments. The strings and woodwinds begin a rising arpeggiation in measure 49, which climaxes in measure 67. Throughout the 135 measures leading up to the vocal entrance, most of the musical material remains fixated on the E♭ arpeggio. Since

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[12] Marc-André Dalbavie, "Pour sortir de l'avant-garde" [Leaving the avant-garde] in *Le Timbre, Métaphore Pour La Composition* [Timbre, a metaphor for composition], ed. Jean-Baptiste Barrière, (Paris: IRCAM/Christian Bourgois Editeur, 1991), 306-307.

[13] In this paper, the pitch naming convention is used, where middle C is C4, the C above that is C5, and so on. E♭1represents the lowest E♭ of the piano.

the figuration tends to begin in the bass range, a connection is made between the arpeggiation and the pedal E♭. The connection between the pedal note and the arpeggios is heightened since the arpeggios tend to move upward from the bass. (An isolated arpeggio in an upper register would not have the same effect.) As the pitches move upwards in register, the relationship between the root (fundamental) and its overtones becomes more clear, and the new instruments enrich the sonority since they themselves have a broad variety of overtones. The obstinate quality of the pedal tone, lasting for 135 measures (and extending into the first scene), combined with the arpeggiation which emanates from the bass note, creates a relationship between the music and the unfolding of the harmonic series.[14] What is startling about the music is that it does not come from the opposition of tonic and dominant; the pedal is a prolonged tonic. This is in marked contrast to another famous opening pedal from around the same time, Brahms' *Symphony No. 1*.

The Brahms *Symphony* begins with a C pedal that lasts for eight measures, over which the violins play an expansive melody. The pedal and the melody return in measure 25 transposed in the dominant. Brahms' use of the pedal tone differs from Wagner's in two ways. First, the first pedal tone introduces the tonic sonority, and the second pedal tone provides an emphasis on the dominant. In the Wagner *Prelude*, there is only one pedal tone. Secondly, the melodic figures in the Brahms are not directly related (through arpeggiation) to the pedal. Because of the chromaticism, the melody strains against the pedal tone, causing harmonic tension and eventually, causing the pedal to move; the melody is perceived as a separate object. In the Wagner, the melodic figures do not create harmonic tension, since they are extensions of the pedal. Under these conditions, one can describe the Prelude as an instance of timbral development. Wagner uses this technique only in the Prelude, and does not return to it during this or any other opera. It remains an

[14] Richard Wagner, *Das Rheingold*, (New York: Dover Publications, Inc., 1985), 1-15.

isolated moment in the realm of nineteenth-century music.[15] Of course, it must be pointed out that the *Prelude* to *Das Rheingold* is the opening of the entire *Ring der Nibelungen* cycle, so its prolonged tonic is both functional and dramatic.

Arnold Schoenberg famously commented on timbre and its role in musical composition. In the final pages of his *Theory of Harmony*, Schoenberg breaks off a discussion of "Chords with more than six notes" to discuss "*Klangfarbenmelodie*":

> In a musical sound (*Klang*) three characteristics are recognized: its pitch, color [timbre], and volume. Up to now it has been measured in only one of the three dimensions in which it operates, the one we call 'pitch'. Attempts at measurement in the other dimensions have scarcely been undertaken to date; organization of their results into a system has not yet been attempted at all. The evaluation of tone color (*Klangfarbe*), the second dimension of tone, is thus in a still much less cultivated, much less organized state than is the aesthetic evaluation of these last named harmonies. …
>
> The distinction between tone color and pitch, I cannot accept without reservations. I think the tone becomes perceptible by virtue of tone color, of which one dimension is pitch. Tone color is, thus, the main topic, pitch a subdivision. Pitch is nothing else but tone color measured in one direction. Now, if it is possible to create patterns out of tone colors that are differentiated according to pitch, patterns we call 'melodies', progressions, whose coherence (*Zusammenhang*) evokes an effect analogous to thought processes, then it must also be possible to make such progressions out of that which we call simply 'tone color', progressions whose relations with one another work with a kind of logic entirely equivalent to that logic which satisfies us in the melody of pitches.[16]

Schoenberg wrote one piece making use of 'tone color melody', the third movement of the Op. 16, *Five Pieces for Orchestra* written in 1909.[17] The title of the third movement, *Farben,* ("colors") has been associated with Schoenberg's concept of *Klangfarbenmelodie.* It has been noted that *Farben* is a remarkable canon that unfolds

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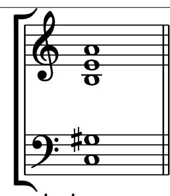
[15] Dalbavie, 307-308; Anthony Cornicello, 23 June 1998. "*Modulations* and *Chants de l'Amour*." Lecture notes from *Ircam Académie d'été*. Presented by Gérard Grisey. Ircam, Centre Georges Pompidou, Paris. Available from the author.

[16] Arnold Schoenberg, *Theory of Harmony*, trans. Roy E. Carter (Berkeley and Los Angeles: University of California Press, 1978), 421.

[17] Arnold Schoenberg, *Five Pieces for Orchestra*, Op. 16, ed. Richard Hoffmann (New York, London, and Frankfurt: C.F. Peters Corporation, 1973).

slowly in 44 measures.[18] However, the rhythmic language of the work deliberately obscures the canon. Schoenberg even directs the conductor to avoid accentuation in the instrumental entrances, "…so that only the difference in color becomes noticeable."[19] There are some motives that appear during the course of the work. But these motives are too brief and disconnected to form a distinct musical line. What is the listener to follow?

The piece begins with the chord C, G♯, B, E, A (see Example 1-2). It is heard again in the middle of the work, measures 250-251, then at measure 259, and finally at the conclusion, measures 263-264.[20] By virtue of its repetition and chronological placement, the chord becomes referential. The chord also appears transposed, but this does not detract from the primacy of the referential chord.[21]



Example 1-2 The referential chord from Schoenberg's Opus 16, Number 3.

Dalbavie argues that the work is focused on timbre and texture.

> *Farben* is first of all a work built around the notion of timbre. All of the processes produce the effect of sliding in a range that rarely exceeds two octaves. All of the riches are found then in the orchestrational work, and in the blending of instrumental colors.[22]

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[18] John Rahn, *Basic Atonal Theory*. (New York: Schirmer Books, 1980), 59-73.

[19] Schoenberg, *Five Pieces for Orchestra,* 31.

[20] The measures are numbered consecutively throughout Op. 16, so the third movement consists of measures 221-264.

[21] Rahn, 64, 68.

[22] Dalbavie, 310. "Farben est avant tout une œuvre constuite autour de la notion de timbre. Tout ce processus produit un effet de glissement dans un ambitus ne dépassant que rarement deux octaves. Tout le richesse se trouve donc dans le travail d'orchestration et de fusion des timbres instrumentaux." (Translation by the author.).

> With *Farben*, Schoenberg lays out the basis of the notion of texture and contrasts it with the notion of timbre, once and for all establishing the line of continuity.[23]

By the "line of continuity," Dalbavie is referring to the musical discourse, which is expressed solely through timbre and texture. If a work has no distinct melody, motive or counterpoint, how can a listener orient him or herself when listening to the piece?

In *Farben*, the listener first encounters the chord shown in Example 1-2, scored for woodwinds, muted brass, and two solo strings. This sonority is kept constant throughout the first phrase, measures 221-231.[24] After the harp entrance in measure 232, the initial sonority returns. The return to the wind/string timbre reinforces the importance of the element in the work. At this point, the listener cannot fail to recognize the timbre as referential. As the referential sonority continues developing, Schoenberg introduces new motives that stand in relief to the sustained nature of the wind/string chord. The referential chord returns in measure 252, orchestrated in a similar manner to measure 221. The similarity in orchestration allows the listener to grasp a return to the initial timbre and texture. The return to this texture comes after a distinct increase in the amount of surface material, which reaches a climax in measures 246-249. The overall effect is that the opening texture is perceived as referential and the other material decorative and contrasting.

The chord in measure 252 represents a return to three different (but related) musical parameters: the initial chord, timbre, and texture. If the definition of timbre were expanded to include pitch, then it can be argued that *Farben* is a work that is concerned primarily with timbre. The referential element of *Farben* is the combination of the initial chord and the orchestration. As Schoenberg moved away from the initial timbre, he changed the texture, making it more chaotic, much less smooth than the movement's opening. The

[23] Dalbavie, 311. "Avec Farben, Schoenberg pose les bases de la notion de texture et l'oppose à la notion de timbre tout en y établissant le lien de continuité." (Translation by the author.).

[24] The measure numbers run continuously throughout Opus 16, so *Farben* begins on measure 221.

return to the referential timbre is accompanied by a return to the same texture. Any other type of texture would have changed the nature of the referential sonority. Therefore it is reasonable to conclude that timbre is at the forefront of the compositional processes in *Farben.*

Schoenberg himself never again used *Klangfarbenmelodie* in the same way as he did in Op. 16 No. 3. Indeed, the term *Klangfarbenmelodie* has become associated instead with Webern, and with European Serialism in the 1950s, and has tended to be used interchangeably with “pointillism.”[25] This is quite distant from Schoenberg’s proposal, which intimates that a coherent melody can be constructed on just one note, with variations in timbre sustaining the continuity. Timbral compositional processes like *Klangfarbenmelodie* does not make any significant appearance in the Second Viennese composers, and does not figure into the works of the mid-century avant-garde composers. True *Klangfarbenmelodie* appears in 1950, in the eighth fantasy of Carter’s *Eight Etudes and A Fantasy*, a study on one note; for Carter, this was an isolated experiment, with the possible exception of “Anaphora” from *A Mirror On Which to Dwell.*[26] No composer made significant use of *Klangfarbenmelodie* until the 1950s, when Giacinto Scelsi began producing his mature works.[27] Many of Scelsi’s works are based on one note or chord, and thoroughly explore Schoenberg’s *Klangfarbenmelodie* principles.

The Wagner and Schoenberg pieces mentioned thus far are isolated experiments on timbre. They fall outside of the type of surface discourse that was common to the music of

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[25] Randel, Don Michael, ed., *The New Harvard Dictionary of Music* (Cambridge, Massachusetts and London, England: The Belknap Press of Harvard University Press, 1986), s.v. “Klangfarbenmelodie.” Pointillism in music has come to mean a style of writing where a musical line is treated, usually simultaneously, to octave displacements, extreme variations in articulation, dynamics, and instrumentation, and is often interspersed with rests. See David Cope, *New Music Composition*, (New York: Schirmer Books 1977), 39; see pages 38-47 for a discussion on pointillism and Klangfarbenmelodie

[26] David Schiff, *The Music of Elliott Carter*, (New York: Da Capo Press, 1983), 145, 282-285. “Anaphora” is based on a fixed chord, which is similar to a *Klangfarbenmelodie,* but not quite the same.

[27] Todd M. McComb, 1992, “Scelsi: Orchestral Works (Survey),” [Internet, WWW]. ADRESSS: <http://www.medieval.org/music/modern/scelsi/orch.html>.

their respective time periods. It is evident that these composers had little interest in pursuing the matter further.

If Schoenberg himself did not produce additional *Klangfarben* works, did other composers do so in a substantial way; that is, did other composers create a surface dialogue that allowed timbre to emerge as a compositional parameter? Certainly. Many 20th century composers have used coloristic devices in their works, such as unusual orchestration or instrumental effects, although not all of these composers would have considered timbre as a compositional element. The development of timbre as a compositional element can be traced through the works of four composers: Debussy, Varèse, Ligeti, and Scelsi. An examination of works of these composers will reveal a trend that increases the importance of timbre in the development of contemporary music.

Debussy

Debussy has often been cited for his unique orchestration, non-traditional scales, and unusual harmonies. Most commentators readily discuss the use of pentatonic scales and chords moving in parallel motion, as well as the frequent use of extended harmonies.[28] These same commentators discuss how Debussy's harmonic application extended the Classical and Romantic traditions. However, Debussy's techniques did not stray too far from tonality. His music was always tonally centered, although he often utilized harmonic elements in an unusual fashion. For instance, dominant 7th chords (and half-diminished 7th chords) do not always "resolve" in traditional ways.[29] Rather than abandoning tonality, Debussy re-interpreted the tonal language to suit his own needs.

The traditional view of Debussy's music focuses predominantly on the pitch structure of the work. Although it is possible to analyze any of Debussy's works through

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[28] For instance, see Ludmila Ulehla *Contemporary Harmony* (New York: The Free Press, 1966), 159-248 for an in depth discussion.

pitch structure, the results may prove less than conclusive. If timbre is brought into the analysis, Debussy's intentions become clearer, and his techniques appear to have a distinct purpose. For example, Debussy often uses a deliberately vague harmonic language in order to avoid the Classical duality of tonic and dominant. He refrains from the methods of common practice tonality when creating structural divisions in a work. Instead, Debussy creates structural articulations with the aid of timbre.[30] In the following example it will be demonstrated how Debussy articulated sections utilizing timbre. "Nuages," the first of the three *Nocturnes*,[31] will be analyzed for pitch structure, and then the effects of timbre will be examined.

Most of the first section of the work (measures 1-63) is built upon an octatonic scale (B-C♯-D-E-F-G-G♯-[A♯]), a hybrid scale derived from the octatonic and whole-tone scales (B-C♯-D-E-F-G-A), and a centricity on B. The middle portion (measures 64-79) is based on D♯ Dorian, and makes strong reference to the pentatonic scale. There is a return to the opening scale and centricity for the closing section (measures 80-102). A closer look at the opening section reveals that the harmonic language deliberately avoids a conclusive reference to the overriding central note (B) of the work. A B♭ minor triad, for instance, approaches the cadence on G in measure 21. The G is prominent throughout the next section of the work, and after a brief move towards C, there is a three-measure pedal on A♭ in measures 39-41(the bass succession is a composing-out of the bass succession in the first phrase of the piece). The next section (measures 43-52) features a B in the bass, instead of the expected G. Debussy also uses B in the bass of the final cadence of the movement.

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[29] Ulehla, 191-6. On 192, Ulehla cites Debussy's *Le Balcon*, where a C dominant 9th (#11) resolves to an E dominant 7th in 2nd inversion.

[30] A definition of timbre would have to include more than the reference to 'tone color' found in [Don Michael Randel , ed. *The New Harvard Dictionary of Music* (Cambridge, Massachusetts and London, England: The Belknap Press of Harvard University Press, 1986), s.v. "Timbre."]. A working definition of timbre has to include orchestration, register, tessitura, dynamics, and articulation, i.e., the characteristics of the particular sound.

[31] Claude Debussy, *Three Great Orchestral Works in Full Score* (New York: Dover Publications, 1983), 32-48.

Debussy is exploiting the fact that the octatonic scale, by virtue of its symmetrical construction, does not have a center. The ambiguous nature of this scale does not provide a true tonic for the first section of the piece. Therefore, any attempt at a traditional view of the work (in terms of the Classical relationship between tonic and dominant) will prove unsatisfactory.

The role of timbre, particularly through orchestration, cannot be overlooked when examining the structure of the work. At the opening, Debussy employs English horn, clarinets and bassoons frequently. He has the clarinets and bassoons playing chords in quarter notes. He also extensively uses the entire string section (often divisi). In the middle section, the harp and flute produce the melody. The flute and harp have had no role in the piece before this section. In the middle section, Debussy makes frequent use of the strings (usually playing sustained triads), but the woodwinds are used sparingly, most often to fill out a chord. The English horn does not appear at all. In the closing section of the movement (measures 80-102), the harp does not return at all, and the flute plays, in the coda, a reminder of the second section's melody. Debussy is clearly associating the first section of the work with the English horn and the second section with the flute.

Of course, many composers have applied orchestration to delineate sectional divisions in a work, so this is not unique to Debussy. Many composers have utilized changes in orchestration as a technique of variation.[32] However in "Nuages," the orchestration is used to associate musical ideas with a particular timbre. For example, the English horn melody is not played by any other instrument. Furthermore, the English horn plays *only* this melody. The same is true, to a lesser extent, of the flute and harp melody of the second section. The flute and harp only play the pentatonic melody of the second section (except as previously noted). When the strings echo the melody (measures 71-74),

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[32] There are many examples of orchestration being employed as a variation technique. One example that comes to mind is the opening measures of the second movement of Tchaikovsky's *Symphony No. 6*. The movement begins with an eight-measure melody in the violoncelli, followed by a varied repetition in the woodwinds.

there is a temporary movement away from the pentatonic scale. The section closes with the flute and harp playing the melody in the pentatonic scale.

The timbral element of “Nuages” can be summarized in the most general terms. The first section of the work is deliberately vague. Debussy takes a literal interpretation of the title (“Clouds”) and creates a harmonically insecure passage, utilizing vagrant harmonic motion.[33] To contrast this, Debussy wrote a deliberately simple passage. The harmonic language is direct and triadic. The second section of *Nuages* stands in stark contrast to the first section, which contains many dominant ninth chords. In many respects, the middle section is the timbral opposite of the opening: where the opening is vague, the middle section is concrete.

To imply that Debussy was a timbral composer would certainly be an overstatement. Debussy was concerned with harmony and melody, much like other composers of his time. However, he was also interested in timbre as a compositional element. For Debussy, timbre was not merely the result of formal processes. Instead, timbre was employed to enrich the formal processes of his work. In “Nuages,” the timbral effects could have been conceived alongside the tonal and melodic devices. Certainly, timbre has a major role in shaping the overall structure of the movement. Unlike his predecessors, Debussy raised timbre to a level more equal to the other elements of musical composition.

Varèse

Varèse’s compositional approach takes Debussy’s timbral concerns a step further, by using non-tonal harmonies. Like Debussy, Varèse was a careful orchestrator, concerned with balance and clarity. Henry Cowell once said, “I have frequently noticed that when Varèse examines a new score, he is more interested in the orchestration than the musical

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[33] Arnold Schoenberg, *Structural Functions of Harmony*, ed. Leonard Stein, revised edition (New York, London: W.W. Norton & Company, 1969), 44-50, and 76-113.

content."[34] His writings and other statements reveal his attitude towards orchestration and timbre:

> To me, orchestration is an essential part of the structure of the work. Timbres and their combination – or better, quality of tones and tone-compounds of different pitch, instead of being incidental, become part of the form, coloring and making discernible the different planes and sound-masses, and so creating the sensation of non-blending.[35]

Varèse's timbral influence on the spectral composers can be demonstrated by examining the idea of static pitch fields, which may be found in most of Varèse's works (such as the opening passages of *Déserts* (1954), and the opening of *Intégrales* (1925)). The idea of held notes, sustained or repeated for many measures, would have been exotic even to the most seasoned new music listener. The concept is especially striking in contrast to the music being created around the time of their composition. For example, compare Schoenberg's *Suite for Piano* with *Intégrales* and Boulez's *Structures* with *Déserts.* The main contrast between the composers' works is the rate of harmonic change. The harmonic rhythm in both the Schoenberg and Boulez works is quite rapid, with the entire chromatic pitch collection being exposed every few measures. The Schoenberg work contains some repetition, and therefore some referentiality, but the Boulez work does not. Varèse's uses of static fields sustain a specific chord for a long duration, and thereby creating a referential sonority for the passage in question. For instance, in *Intégrales*, the first chord and the clarinet motive (and its variations) is reiterated several times during the course of the first 29 measures of the work. Example 1-3 shows the clarinet incipit and the chord that is introduced in the fifth measure.[36] The chordal elements, shown on separate staves, are

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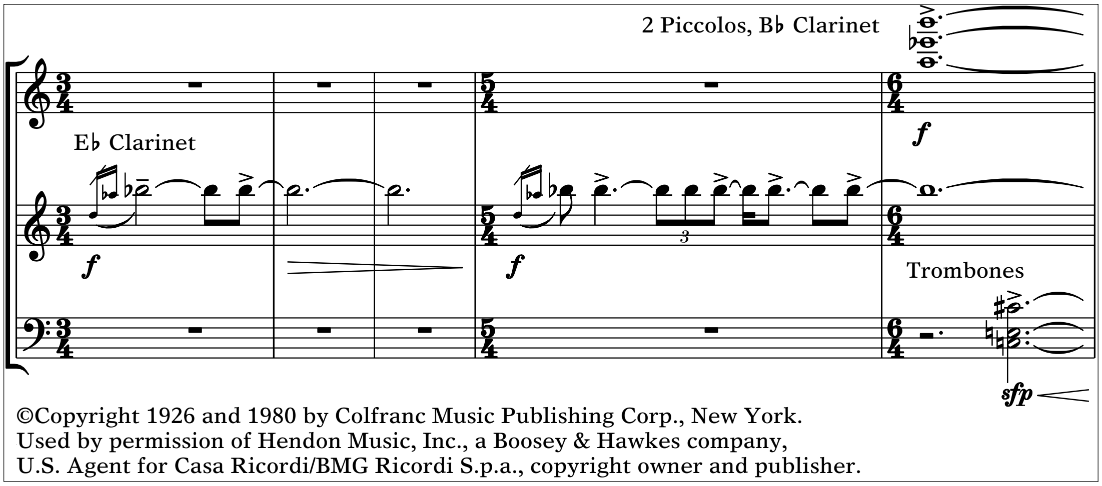
[34] Henry Cowell, *American Composers on American Music*. (Stanford: Stanford University Press, 1933) 43-44; Quoted in Fernand Ouellette. *A Biography of Edgard Varèse*, trans. Derek Coltman, (New York: The Orion Press, 1968), 60.

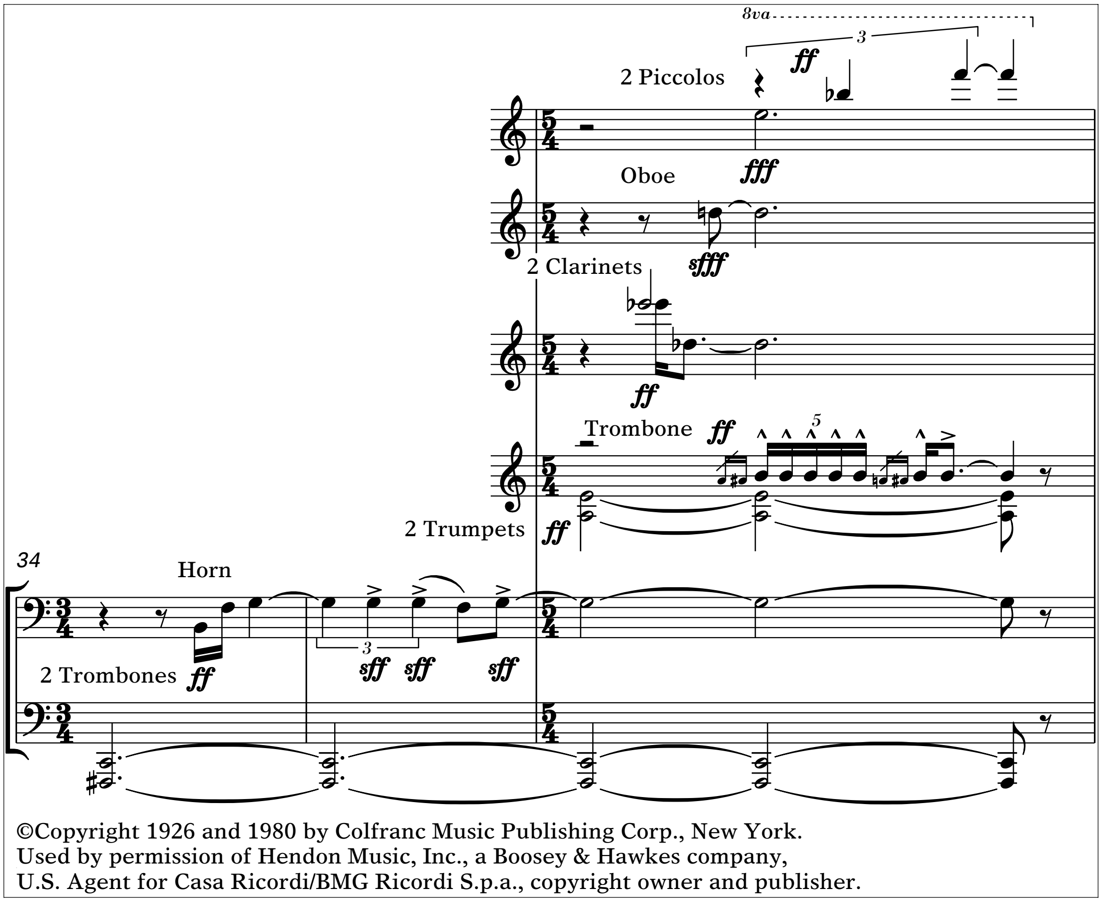
[35] Edgard Varèse and Alexei Haieff, "Edgard Varèse and Alexei Haieff Questioned by 8 Composers," *Possibilities*, (winter issue 1947-48); quoted in Fernand Ouellette *A Biography of Edgard Varèse*. Translated by Derek Coltman (New York: The Orion Press, 1968), 200-201.

[36] There is a great deal of non-pitched percussion writing throughout this section (indeed throughout the entire work). The elements shown in Example 2-3 account for all the pitch material during the first 29 measures.

sounded separately (although overlapping) several times during the first 29 measures. The next section begins after a three-measure percussion soli. A similar process (lasting 22 measures) is initiated, with the elements in Example 1-4.



Example 1-3 Varèse, *Intégrales*, measures 1-5, winds and brass only.



Example 1-4 Varèse, *Intégrales*, measures 34-36, winds and brass only.

By the sheer amount of repetition, Varèse creates not only a referential chord but also a referential sonority. The elements are not re-scored for variety's sake or for the sake of development. When a motive appears in a different instrument, there is a distinct change in the music. For instance, the opening clarinet passage appears in the trumpet in measure 10, and again in measures 18-21. Each time, Varèse creates variations of the motive that are unique to the trumpet. In a similar fashion, Varèse gives the oboe its own distinct variation of the melody in measures 12-13. The clarinet consistently returns with the motive, each time followed by the chord in the winds and trombones. This is not always the case with the trumpet and oboe statements of the motive. When the trumpet has the motive in measure 10, the answering chord appears in measure 11. The chord is not sustained. It is re-articulated after the third beat in the measure. The chordal attacks during the first beat are actually an anticipation of the real appearance of the chord during the third beat. The oboe motive in measure 12-13 and the trumpet motive in measures 18-21 is not answered by the chord. What the listener becomes accustomed to is the melody in the clarinet answered by chord. During the entire passage in question, Varèse constantly varies the distance between the start of the opening motive and the onset of the chord, as well as the variations on the motive and the differences in attacks for the chord. Essentially, the character of the music varies directly with the orchestration of the opening motive.

Throughout measures 1-29, and in the following passage, measures 32-52, Varèse continues the same orchestration for the chords. In the latter section, the repeated notes in the trombone (see Example 2-4) are unique to that instrument. By finely controlling the orchestration of the static fields, Varèse is associating a distinct harmony with a distinct timbre. During the first section, whenever the clarinet does not have the melody, the timbre is varied or incomplete. When the clarinet returns with the melody, the timbre returns in full (see Example 1-3 for the clarinet melody and wind chord).[37]

The first section can be broken down into three distinct sub-timbres: the clarinet melody (and its variants), the upper wind chord, and the lower brass chord. During the section, Varèse develops the timbres by their duration, intensity, and combination. Only at the end of the section do all the sub-timbres join forces to create the composite timbre of the section. The second section has a similar developmental scheme, with four distinct elements: the low trombones, the horn, the group of woodwinds and trumpets, and the trombone (see Example 1-4).

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[37] This is not meant to discount the effects of the percussion, which provides a backdrop of constantly varying texture. Non-pitched percussion is beyond the scope of this paper since the focus is on timbre as a function of pitch.

Varèse was not interested in motivic development in the traditional manner.[38] Instead, he was concerned with the association of unique harmonies and timbres, and the projection of timbres through the course of the piece. Development in a Varèse work can involve variations in the manner in which the timbres are juxtaposed, overlapped, or combined. If the timbre is changed, even slightly, there is a similar change in the harmony or some other facet of the presentation.[39] Varèse did not develop the opening clarinet phrase[40] so much as the timbre of the clarinet playing that phrase. The variations presented by the clarinet are more like extensions of the opening phrase. The same can be said of the chords in the winds and brass. When the chords have a chance to sound together in measure 27, Varèse creates a new chord, different from the original in pitch, but having similar characteristics to the original chord. The new chord's timbre resembles that of the chord in Example 1-3, particularly the registral separation between the high woodwinds and low brass, but the pitches are different. The listener is aware that there is a new timbre, and that it is related to a previous timbre. For the climactic chord, Varèse utilized all the available pitched instruments. This drastically changes the timbre, and so Varèse chose to alter the chord. The chord is modified by greatly expanding its range and increasing the dissonance. In the syntax of *Intégrales*, a change in harmony is clearly associated with a transformation of timbre. A conclusion may be drawn that Varèse considered the harmony and timbre as a fused mass.

Ligeti

Ligeti had a profound impact on European and American music during the 1960s when his 'texture' pieces were first performed. Much has been written about these works

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[38] Traditional, as in the "developing variations" techniques found in the music of Bach, Beethoven, Brahms, and Schoenberg.

[39] For instance, the unanswered oboe phrase in measure 12 of *Intégrales*.

[40] The phrase has no true consequent, such as a complementary phrase that reaches a cadence. The chords provide an 'answer', but without closure.

with respect to their textures.[41] The focus of this section will be on how Ligeti utilized timbre in his works of the 1960s.

Ligeti's 1960 work *Apparitions* was his first well-known work to employ what Ligeti would eventually call 'micropolyphony'. 'Micropolyphony' is a collection of techniques that emphasize sustained sounds or extremely fast repeated phrases, avoid a sense of pulse, and stagger instrumental entrances; the result is usually a sound mass.[42] Micropolyphony usually involves thick, densely packed textures created from chromatic clusters. The texture often results from a "…simultaneity of different lines, rhythms, and timbres."[43] Except in rare cases, no single voice is meant to be distinguished from the whole. In many of Ligeti's early works, *Apparitions*, *Atmosphères* (1961), and *Volumina* (1961-62) he makes use of chromatic clusters which remove melody, harmony, and rhythm as distinct features. The individual elements of a micropolyphonic work are not to be heard separately from the whole. The listener only perceives a composite ensemble timbre. Micropolyphony is Ligeti's technique of sustaining and developing a timbre without clearly activating the surface.

Ligeti's music evolved throughout the 1960s. He incorporated strict (but slow moving) canons in *Lux aeterna* (1966), the *Cello Concerto* (1966), and *Lontano* (1967),[44] expanding his use of micropolyphony. Gérard Grisey cited *Lontano* as an enormously influential work. He spoke of the work's slow timbral progression as an inspiration for him to try to create a timbre-based music.[45] The timbral elements of *Lontano* are illustrated in Example 1-5, which documents the pitch and timbre motion from the first 41 measures of the piece.[46] What the reduction does not reveal is the micropolyphony, the layering of

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[41] For instance, see the chapter titled "Texture" in Cope, 223-237.

[42] Paul Griffiths, *Modern Music and After* (London: Oxford University Press: 1995), 136.

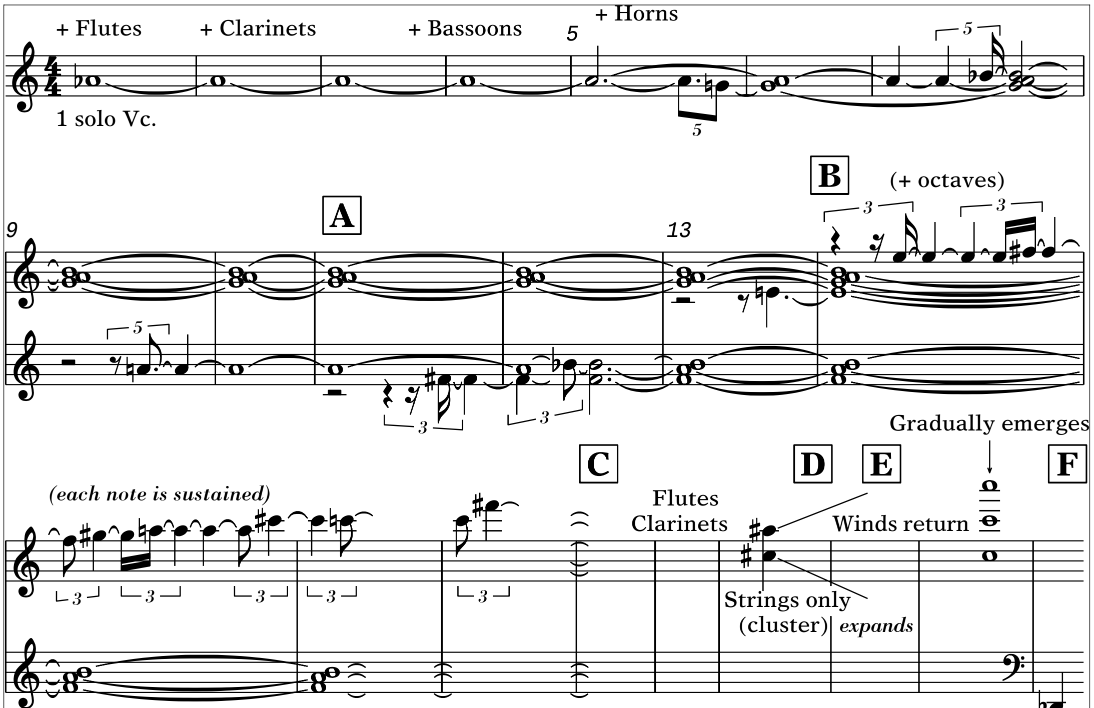
[43] Cope, David, *Techniques of the Contemporary Composer*, (New York: Schirmer Books, 1997), 101.

[44] Stanely Sadie, ed. *The New Grove Dictionary of Music and Musicians, Vol. 10*. (Hong Kong, London, New York: Macmillan Publishers Limited, 1980), s.v. "György Ligeti," by Ove Nordwall.

[45] Gérard Grisey, 20 June 1998, conversation with the author, Paris, France.

[46] Györgi Ligeti, *Lontano for full orchestra*, (Mainz: B. Schott's Söhne, 1969).

many voices on the same note. Example 1-6 is a reproduction of the first four measures of the piece. All of the instruments (four flutes, four clarinets, three muted bassoons, and two solo cellos) are playing the same A♭. The result of the entire passage is a timbral crescendo climaxing after rehearsal letter D.



Example 1-5 Ligeti, *Lontano*, reduction of the first section. This schematic diagram is intended to show the salient features of the progress of the pitch range and the timbral crescendo in the first 41 measures of the piece. After letter C, only the extremities are shown, with the exception of the triple-octave pitch C that emerges towards the end of the section.

Example 1-6 Ligeti, *Lontano*, measures 1-4.

Lontano's tempo is slow (♩ = 64), and its harmonic rhythm even slower. The A♭ remains throughout the entire section and slowly changes instrumental color. Ligeti gradually shifts the color throughout most of this piece. A note is sustained and developed by constantly and subtly dovetailing the note into other instruments. Most of the entrances are very soft, so that the color of each particular instrument gradually transforms the color of the note. As each instrument plays the A♭ a timbral crescendo is created. The timbral crescendo extends as Ligeti introduces each new pitch.

Looking at Example 1-5, it becomes apparent that there is much more than pitch expansion in the work's first section. Pitch remains an important element in Ligeti's music, but the pitch choice (and pitch density) is magnified by the timbres and their transformation. For instance, the opening woodwind unison is expanded to a small cluster, which eventually includes strings. The cluster is expanded further and then includes only strings; and a new element, the triple octave C emerges and an arrival is created, or a cadence, at which point the music ceases to move forward for a while. The timbral procedures are halted, and for several measures, the C is the only pitch heard. The entire section is a timbral crescendo leading from the opening unison to the triple octave. Similar processes guide the remaining sections of *Lontano.*

The surface of *Lontano* is guided by timbral development and pitch expansion. The timbral development itself is shaped by Ligeti's micropolyphony so that the color of each pitch is constantly in flux. On certain levels, *Lontano* is a work that is driven by sustained notes, but the surface activity (the micropolyphony) gives the impression of a work in a constant state of motion. The micropolyphony is the constant re-articulation of one or more notes, each note generally being sustained (in the respective instruments) for several beats.[47]

Ligeti's harmonic motion (in the 1960s music) does not rely on tonal voice-leading principles. The vague quality of the harmonic language (clusters), orchestration (quiet entrances), and rhythmic language (sustained notes) does not invite the listener to focus on any single musical strand. This is not to discount the element of pitch, for Ligeti was evidently very careful about the introduction of pitches during the section examined. The timbral development only seems to supercede the pitch development in *Lontano* and other works of this period, but Ligeti's pitch choices guide the work's development and create a strong focus.

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[47] Ligeti's use of micropolyphony in *Lontano* may be contrasted with that found in the *Chamber Concerto.* In the latter, the surface is activated by fast tremolo-like passages that similarly sustain and develop a timbre.

Scelsi

Giacinto Scelsi was born in 1905, living most of his life in Italy, eventually settling in Rome. Despite his creativity and originality, he wrote in relative obscurity until 1987, when several of his works for orchestra and chorus were programmed on an ISCM festival in Cologne.[48] He had a direct influence on the music of Tristan Murail, after Murail met Scelsi while studying in Rome.[49] Murail kept in contact with the elder composer for years.[50] Scelsi's music is described by Julian Anderson as "…radically static…focusing upon narrow pitch bands (often single notes or octaves), [with an] emphasis upon timbre for its own sake, [and makes] frequent use of microtones…". [51] These elements of Scelsi's music attracted the ears of the spectral composers in their formative years.

Scelsi's early music (late 1930s) was twelve-tone, but by the mid-1950s he became dissatisfied with the pitch language.[52] Following a mental breakdown, Scelsi began playing the piano, "endlessly playing the same note and immersed in concentrated and intense listening…".[53] The result was a startlingly new kind of music, where the surface discourse is the changing timbres of a single note or chord. Unlike Ligeti's music of the 1960s, many of Scelsi's works are based entirely on one note, or the motion between two notes.[54] Scelsi seems to have accepted the challenge of Schoenbergs' *Klangfarben* manifesto, writing

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[48] Harry Halbreich, "Giacinto Scelsi" biographical notes to *Giacinto Scelsi: Quattro Pezzi per Orchestra, Anahit, Uaxuctum* trans. Elisabeth Buzzard, CD 200612 Accord, 1989, 20.

[49] Brian Morton, and Pamela Collins, eds. *Contemporary Composers*. (Chicago, London: St. James Press, 1992), s.v. "Tristan Murail" by Julian Anderson, 672-73.

[50] Tristan Murail, 4 December 1998, *Re: Désintégrations*. [Internet, email to the author] Available: Available as e-mail from the author, <a-mcorn@pop.ma.ultranet.com>.

[51] Morton and Collins, 673.

[52] Halbreich, 20.

[53] Ibid., 20.

[54] Griffiths, "Modern Music," 255.

music based entirely on timbral development with a minimal concentration on pitch. Most interesting is the fact that many of Scelsi's innovations predate those of Ligeti.

Scelsi's early mature music includes the 1959 work *Quattro Pezzi per Orchestra (Ciascuno su una nota)*.[55] The piece is scored for a chamber orchestra of 26 players, and each of the four movements is based on (and around) one note, in order: F, B, A♭, A♮. Despite the title, Scelsi's works rarely intone only one pitch. Instead, the pieces often emanate from a single pitch or chord, and periodically return to the same note. A timbral evolution takes place during the course of a work or movement. At the start of the first movement of the *Quattro Pezzi*, microtonal trills as well as glissandos moving away from the F4 on which the movement is based, are introduced. (See Example 1-7 for a demonstration of these devices.) Halbreich stated that the work was built upon a "…structure defined by the three parametric layers…whose climaxes do not necessarily coincide: unfolding of the tessituras (from unison to four octaves), dynamics, and tonal density."[56]

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[55] *Four Pieces for Orhcestra (each on one note).*

[56] Halbreich , 24.

Example 1-7 Scelsi, *Quattro Pezzi per Orchestra*, movement 1, measures 6-9. All parts are notated at sounding pitch.

In the second movement, Scelsi produces a similar treatment, consisting of microtonal trills and glissandi, focused on B. The second movement is nearly twice as long as the first movement. The pitch range for the first and second movements are almost equal. There is no correspondence in Scelsi's music between the duration and ambitus of the pitch structure. The second movement begins and ends with a long focus on B. Nearly two-thirds of the way into the piece there is a motion towards C. Example 1-8 extracted from the second movement shows the movement from B to C. Note the microtones, which cause a gradual shift from B to C. The motion back to B occurs at the end of the example, where the microtonal shift creates a progressive downward motion.

Example 1-8 Scelsi, *Quattro Pezzi per Orchestra,* movement 2, measures 59-64. All parts are notated at sounding pitch.

In the third movement Scelsi introduces sub-harmonics, a reference to an inverted harmonic series. The final movement, centered on A, is a summation of all the processes of the previous movements.[57]

The timbral processes applied in these pieces (and many other Scelsi works) are similar to the micropolyphony of Ligeti. Many instruments are employed to color a single note. However, Ligeti's conception of *Lontano* was for a smooth, unaccented musical line, whereas Scelsi's music is filled with unexpected breaks and sudden attacks.[58] Ligeti was concerned with the gradual expansion of the pitch ambitus, whereas Scelsi utilized a small pitch range. If the pitches were to move from A to B♭ for instance, Scelsi would begin a very slow glissando, rather than gradually introduce the new pitch in the manner of Ligeti.

The extremely slow and controlled nature of Scelsi's music had a profound impact on the spectral composers. Spectral music is based on the idea of the gradual transformation of a musical sonority. The transformation could unfold in the manner of Ligeti, utilizing a timbral crescendo, or by the timbral evolution of Scelsi. Both techniques enable a composer to shape a large portion of a piece based on a single sonority. Scelsi's concept of a gradual evolution of a sonority had a particular resonance with composers who were also involved with electronic music. There have been many attempts to unify the processes of electronic and acoustic music,[59] yet Scelsi's timbral evolution provided an inspiration to composers who wished to "…exteriorize the inner reality of sound, to project its inner dynamics into an acoustic space and time…".[60] Scelsi's music, focused on the timbral evolution of note or chord, approximates a temporal projection of the spectrum.

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[57] Ibid., 24.

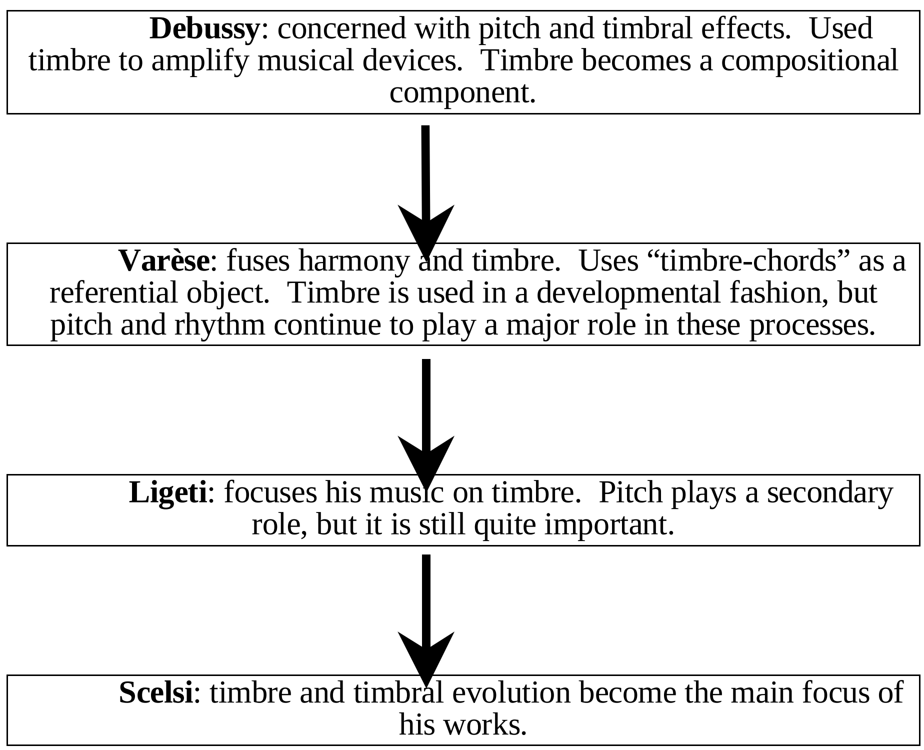
[58] For instance, the first movement of Scelsi's orchestral work "Aion" features many unexpected percussion outbursts.

[59] For example, Stockhausen, Karlheinz, "…wie die Zeit vergeht…" *Die Reihe* 3 (Vienna: Universal Edition, 1957). [English edition, titled "…how time passes…," trans. Cornelius Cardew (Bryn Mawr: Theodore Presser Company, 1959).

[60] Moscovich, 27.

Timbre is not used in Scelsi's works to highlight a certain musical feature (a new musical idea, a structural downbeat, etc.); it *is* the main musical feature.

It is now possible to trace a direct path demonstrating the growing importance of timbre in the works of several 20th Century composers. The following diagram illustrates the trend from Debussy to Scelsi:



These composers created a surface discourse that allowed timbre to develop as a compositional parameter. By the time of the works of Scelsi, timbre alone accounts for most of the musical discourse. Spectral composers believe that timbre and harmony are fused into a single sound-object, and this sound-object is a building block for the composition. This is not to imply that spectral composers are timbral composers in the manner of Ligeti or Scelsi.[61] For a spectral composer, the sound-object becomes an all-encompassing component of the work, generating harmony, melody, rhythm, form, and orchestration.

The influences on spectral music are not limited to the field of music composition for acoustic instruments. Technology, beginning in the Industrial Age, and continuing today, has provided the spectral composers with a wealth of information on acoustics. And the field of electronic and computer music has paved the way to timbral explorations outside the realm of traditional musical instruments.

Part Two: Technological Influences on Spectral Music

The history of acoustic studies is as complex as the history of music itself. This section will be devoted to the acoustic studies that had a direct impact on the development of electro-acoustic and computer music, both of which had an impact on spectral music. Spectral composers became interested in the precise nature of overtones. This is especially true of Grisey, who studied acoustics with Emile Leipp at the University of Jussieu in the early 1970s, and conducted research on instrumental spectra.[62] Only those acoustic studies that examined the nature of overtones will be discussed here. This section will provide an overview of the research and computer music applications, as well as introduce some of the terminology of computer music.

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[61] A look at Gérard Grisey's article "*Tempus ex Machina*: A composer's reflections on musical time," *Contemporary Music Review* 2 (1987): 239-275 will reveal the composer's attitudes toward rhythm, tempo and form. Certainly, the more recent spectral works, such as Grisey's *Vortex Temporum I, II, III* (1994-95), show a concern for more than timbre.

[62] Dalbavie, 321. See also Curtis Roads,, John Strawn, Curtis Abbott, John Gordon, and Philip Greenspun, *The Computer Music Tutorial*. (Cambridge, Massachusetts and London, England: The MIT Press, 1996), 533-609 for a study on spectrum analysis, as well as 144-156 for a discussion on analysis/synthesis (where a sound is synthesized based on the overtone structures of a given sound.)

Acoustic studies

Until the mid-1700s, most of the research on the overtone series had been related to intevallic studies. It was known that a vibrating string produced harmonics, but little was known about vibrating columns of air. Bernoulli's studies of 1753 and 1762 focused on the overtones of wind instruments, specifically on the closed organ pipe. He found that only the odd-numbered harmonics (1-3-5-7…) were present.[63] The idea that the presence (or absence) of certain overtones has a direct influence on the timbre of the sound was an important discovery. It was not until 1822 that a significant study was published on the relationship between overtones and timbre. The French engineer Jean Baptiste Fourier (1768-1830) stated that periodic (complex) waveforms could be broken down into simple sine waves (a wave form with no overtones) of different amplitudes, frequencies and phases.[64] This theory forms the basis for the modern conception of timbre.[65]

In the nineteenth century Helmholtz conducted a great number of experiments in acoustics, but made a significant contribution in the field of combination tones. If two 'pure' tones are sounded, the ear creates a third tone that is either the sum or difference between the two tones. Helmholtz concluded that the ear provides a non-linear response to aural stimuli. Therefore, the overtones can explain some of the characteristics of the musical instrument's sound, but not all of them.[66] Acoustic phenomena like sum and difference tones were to play a major role in the development of electronic music, where these qualities would become exploited to create new and unusual sounds.

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[63] Stanley Sadie, ed. *The New Grove Dictionary of Music and Musicians, Vol. 14*. (Hong Kong, London, New York: Macmillan Publishers Limited, 1980), s.v. "Physics of Music," by Sigalia Dostrovsky, James F. Bell, and C. Truesdell, 667-68.

[64] Curtis Roads, and Philip Greenspun, "Fourier Analysis," in *The Computer Music Tutorial*, ed. Curtis Roads (Cambridge, Massachusetts and London, England: The MIT Press, 1996), 1075-76.

[65] Fourier analysis eventually found its way into computer music, as the Fast Fourier Transform (FFT) was created by James Cooley and John Tukey in 1965 (see Roads and Greenspun, 1076). Variations of this algorithm can be found in many current computer music programs.

Electronic and Computer Music Techniques

This section is intended for the reader who may lack familiarity with electronic and computer music terms and techniques. Electronic music techniques like these are used not only to produce the electronic component in an electro-acoustic work, but are also used by spectral composers to create harmonic units. For instance, a low piano note may be analyzed to produce a list of the strong partials in its spectrum. The composer may then filter the results so that all that remains are the notes between C3 and F♯5. That group of notes may then be modulated by frequency modulation, and so on. The composer then realizes the final results of these operations, often respecting the relative dynamics of the spectrum. The weighting of each note in the spectrum has an influence on the instrumental dynamics, whether or not the composer will likely emphasize the pitch, as well as orchestration (one would not give a weak partial to an un-muted trumpet playing ***f***, for instance).

Additive Synthesis

The production of 'pure' electronic music (that is, music not made up of altered "natural" acoustic sounds) was based on two techniques: *additive synthesis,* the "summation of elementary waveforms to create a more complex waveform,"[67] and *subtractive synthesis,* where a complex waveform is filtered.[68] The technique of additive synthesis is a direct result of the studies of Fourier: if a sound can be analyzed as the product of many overtones at different strengths, then that sound can be reproduced by adding together the overtones in the same strengths.

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[66] Sadie, "Physics of Music," 673.

[67] Curtis Roads and others, 134.

Early synthesis was able to create unusual sounds using additive techniques, but the sounds did not approach those found in nature. Mainly, natural sounds have a time-varying harmonic spectrum. Secondarily, most sounds have a huge number of overtones, many of which are barely audible.[69] To recreate a natural sound using analog (pre-computer) techniques would require a large number of oscillators (the Murail piano example would require more than 100)[70], each of which would need to have its amplitude individually controlled. Even the modular synthesizers created by Moog or Arp would be incapable of such precise and expansive control.

Clearly, the early works using additive synthesis did not try to directly replicate nature. Stockhausen's *Electronische Studie I* makes use of additive techniques, and is constructed using inharmonic[71] partials. *Studie II* is built upon a scale of the constant interval $25\sqrt{5}$,[72] and Stockhausen utilized subtractive synthesis to create narrow frequency bands.[73]

The techniques of additive synthesis are more easily and precisely achieved on a computer. Primarily, there are no hardware restrictions. Theoretically, a composer can create an additive sound using any number of oscillators limited only by the computer's power and storage capacities. The computer can create the demanding envelopes needed to shape the complex overtone relationships. With the advent of programs such as Music V, Cmusic, and Csound, a composer can program "convincing" additive synthesis.

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[68] See the next section for a discussion on subtractive synthesis.

[69] See Murail's analysis of a piano spectrum in Murail "Spectra and Pixies" 161-162.

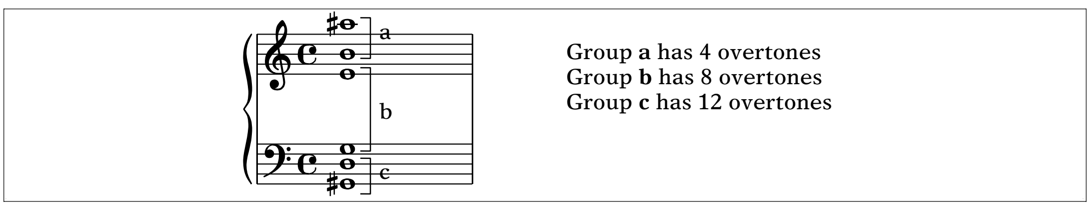
[70] See Appendix II for a reproduction of Murail's spectral analysis of a piano tone.

[71] A harmonic spectrum follows the overtone series (see Appendix I), the frequencies of which are additive multiples of the fundamental. A harmonic spectrum over 27.5Hz would begin with the sequence 55Hz, 82.5Hz, 110Hz, 137.5Hz, 165Hz, 220Hz, and so on. One does not need to have all the notes present to have a harmonic spectrum. An inharmonic spectrum is not constructed in this fashion. The spectrum 27.5Hz, 60Hz, 97Hz, 137.587Hz, 145Hz, 198.7171Hz is not harmonic. In the case of many inharmonic spectra, it is possible to identify a theoretical fundamental, which may exist well below the audible range. If this were true, it would be safe to label the spectrum as inharmonic.

[72] Robin Maconie, *The works of Karlheinz Stockhausen*, (London, Boston: Marion Boyars Ltd, 1976), 71.

[73] Ibid., 77.

In 1969, French composer Jean-Claude Risset wrote a compendium of computer music instruments entitled “Introductory Catalogue of Computer Synthesized Sounds.” [74] One of the more interesting sounds is described by Risset as “Spectral Analysis of a Chord” (Risset #500, reproduced in Gather as 02_01_5).[75] In this example, “for each note of the chord successive harmonics are introduced gradually.”[76] Each note of the chord (see example 1-9) has a different number of harmonics, as shown below, which are gradually introduced during the nearly twenty second development of the single sound. To further soften the effect of the overtones, each overtone makes use of a parabolic envelope, creating a moderately slow attack and decay. This slowly developing sound was contrasted with a percussive sound created from the same harmonic structure (Risset #501, reproduced in Gather as _02_01_5B).[77] The only variation between the two examples is that Risset #501 makes use of shorter envelopes. All the overtones use the same percussive attack and quick decay. The resulting sound is bell-like in character.



Example 1-9 Risset, *Example 500*. The notes with the more overtones (group ‘c’) take the longest to unfold in Risset’s example.

Risset’s studies would prove influential on the spectral composer, since his primary goal was the exploration of timbre. While some of the synthesized sounds are intended to replicate an existing instrument, many of the examples deconstruct sounds, allowing the

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[74] Risset’s book is apparently out of print, and the computer examples were created for a program called Music V, a program no longer in use. However, John-Phillip Gather.’s *Amsterdam Catalogue of Csound Computer Instruments 1.1*. (Buffalo, New York: by the author, 1995) replicates Risset’s examples and updates them to Csound.

[75] Gather, 34-35.

[76] Ibid., 34.

[77] Ibid., 36-37.

listener to hear the microstructures of the sound. If properly deconstructed, the overtones of a particular sound will begin to sound as individual elements, much like the pitches of a chord. However, as in Example 1-9, the ‘chord’ is in actuality a single timbre (in this case, a bell); any change in the pitches of Example 1-9 would create a stark change in the bell’s timbre. One can see that the timbre-chord has is origins in Risset’s timbral experiments.

Further examples of additive synthesis sounds include another work by Risset, *Inharmoniqu*e, John Chowning’s *Stria*, Jonathan Harvey’s *Mortous Plango, Vivos Voco*, and *Déstintégrations* by Tristan Murail.[78] The Murail work is based upon the broader technique of analysis/re-synthesis, where a specific sound is analyzed and reconstructed. Roads discussed several possible musical transformations using analysis/re-synthesis techniques, such as “replac[ing] some envelopes from one sound with selected envelopes from another sound” to create a hybrid timbre.[79]

Most importantly, at least for the purpose of this study, was the application of these techniques to orchestration and composition. Grisey discussed how the early spectral works, as well as the more recent, combined the principles of additive synthesis to their techniques. “We were naïve then - each overtone was to be played by one of the instruments in the orchestra,”[80] meaning that there was little concern for the fact that each instrument does not produce a sine wave. However, the idea was not to replicate a sound that could be produced by an acoustic instrument, but to create new and unusual harmonies using these spectra. In the IRCAM lecture quoted above, Grisey was discussing his work *Modulations* where the harmonies were derived from the analysis of a muted trombone. Since a number of distortion techniques were applied to the harmonic series, it is evident that the purpose of the piece was not literally to re-create the sound of a muted trombone.

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[78] Roads and others, 143-146.

[79] Ibid., 147.

[80] Cornicello, “*Modulations* and *Chants de l’Amour*”.

Filtering, or Subtractive Synthesis

Filtering or *subtractive synthesis* is "the use of filters to shape the spectrum of a source sound."[81] The source sound may be a synthesized timbre or it may be a recording of 'natural' sounds. Filters generally come in four different basic types: **lowpass**, **highpass**, **bandpass**, and **bandreject** :

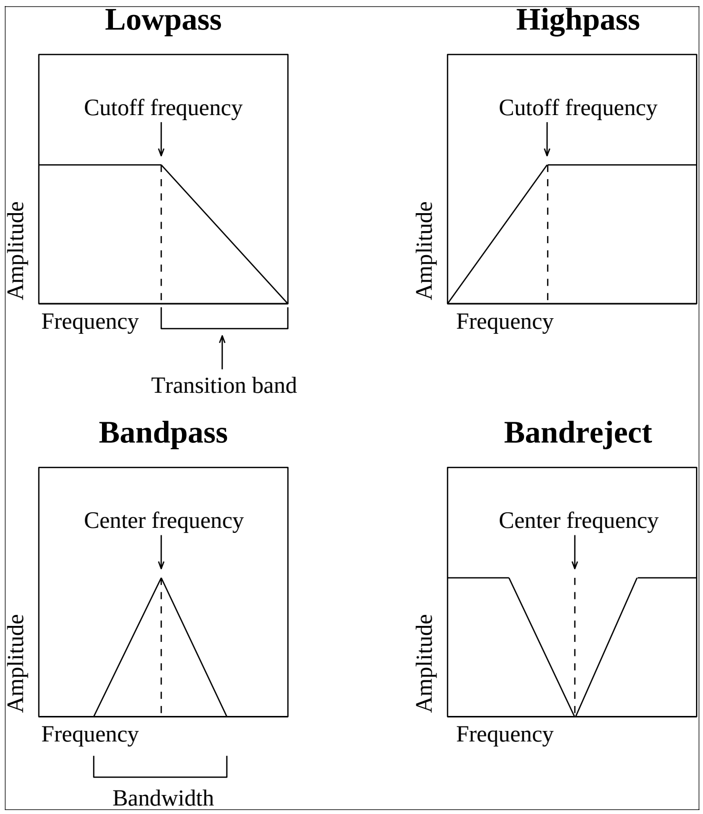

Figure 1 Basic types of filters. Note the *transition band* in the lowpass filter, and the *bandwidth* in the bandpass filter. The transition band and the bandwidth also occur in the highpass and bandreject filters, respectively.

All filters share some characteristics. Primarily, they allow certain frequencies to pass through the filter (hardware or software, that is) unaffected while removing others. In

[81] Roads and others, 184.

a lowpass filter, the frequencies below the cutoff frequency (see above) are allowed to pass, while the opposite holds true for a highpass filter. The filtered are gradually attenuated depending on the range of the transition band (see above) and the slope of the cutoff. The slope may be set to move immediately to zero amplitude, so that no frequency above (or below) the cutoff frequency will appear in the sound.[82]

The bandpass and bandreject filters both have a center frequency rather than a simple cutoff frequency. As the name implies, a bandpass filter allows a given bandwidth through the filter while attenuating frequencies above and below the center frequency. The bandpass filter is also called a resonating filter, because the center frequency can be used to amplify a given frequency. The effect is like resonance if the center frequency is held constant during a musical passage. The bandreject filter, sometimes called a notch filter, works in the opposite manner, attenuating frequencies around a center frequency.[83]

Modulation Synthesis

In *modulation synthesis*, one signal (the *carrier* or **C**) is varied by the application of a second signal (the *modulator* or **M**). Modulation synthesis is a faster (usually audio level) and controllable version of existing musical phenomena. Traditional instrumental techniques make use of this type of technique. Tremolo creates a slow variation in amplitude, while vibrato produces a variation in frequency. Both of these techniques are used as ornamentation on a note, and both variations make use of sub-audio modulating frequencies.[84] If the modulating frequency were to move into the audible range, sidebands will begin to appear, adding new frequencies to the spectrum of the carrier signal. These

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[82] Ibid., 187-188.

[83] Ibid., 188-189.

[84] The audio frequency begins at around 20Hz. A normal vibrato is usually around 4-5Hz.

new frequencies can create complex sounds. If the modulator signal is varied over time, the resulting spectrum may imitate natural sounds.[85]

Three types of modulation will be discussed in this section. *Amplitude modulation* (**AM**), *ring modulation* (**RM**), and *frequency modulation* (**FM**) have had a considerable influence on the nature of sound synthesis. AM and RM are older techniques, and both were used by Stockhausen in many of his works of the 1960s and 1970s (for instance *Mantra*).[86] One cannot discuss AM synthesis without mentioning the influential work of James Dashow. Dashow's research is predicated on the compositional application of spectral construction, so that a specific dyad could be utilized to create a variety of timbres.[87] FM is a more recent technique, analyzed and codified by John Chowning as indicated in his seminal 1973 article.[88] Amplitude modulation and ring modulation synthesis involve introducing a fast tremolo (audio level modulator) into the amplitude domain. Because of the high frequency of the modulating signal, sidebands occur. Sidebands are "frequencies added to the spectrum of the carrier, (typically on either side of the carrier)."[89] The same is true of FM synthesis, where a fast vibrato is introduced in the frequency domain of a sound.

The application of audio level amplitude modulation to a carrier signal produces what are known as *sum* and *difference* tones. If a carrier signal of 1000Hz is modulated by a 428Hz signal, sidebands of 572Hz(C-M) and 1428Hz(C+M) will be added to the

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[85] Ibid., 215.

[86] Maconie, 284-291.

[87] James Dashow, "Looking into *Sequence Symbols*," *Perspectives of New Music* 25 (Winter and Summer 1987), 112. The article also refers to other important articles: James Dashow, "Three Methods for the Digital Synthesis of Chordal Structures with Non-Harmonic Partials," *Interface* 7 (1978), 69-94; James Dashow, "Spectra as Chords," *Computer Music Journal* 4:1 (Spring 1980), 43-52; and James Dashow "New Approaches to Digital Sound Synthesis and Transformation," *Computer Music Journal* 10:4 (Winter 1986).

[88] John Chowning, "The Synthesis of Complex Audio Spectra by Means of Frequency Modulation," *Journal of the Audio Engineering Society* 21(7), 1973. Reprinted in *Foundations of Computer Music*, ed. Curtis Roads and John Strawn (Cambridge, Massachusetts and London, England: The MIT Press, 1985), 6-29.

[89] Roads and others, 215.

spectrum. If either the carrier signal or the modulating signal is not a sine wave, then more sidebands are possible. If the carrier has two overtones for instance, then the above formula must be replicated for each overtone: ((C*2)+M) (C*2)-M), ((C*3)+M) ((C*3)-M). The sidebands are present at a significantly lower volume than the carrier frequency.[90]

Ring modulation is a special form of amplitude modulation. In ring modulation, the sum and difference tones are present at equal volumes to the original carrier signal, but the carrier signal itself is not present. The only audible signal will be the sidebands created by the modulation process.[91]

In both RM and AM synthesis, the harmonic content is determined by the relationship between the carrier and modulator. The previous AM example generated 428Hz, 572Hz, 1000Hz, and 1428Hz. The resulting sound would be considered inharmonic, since the spectrum does not reproduce a harmonic series.

Frequency modulation can produce complex results with very simple means. For instance, a sine wave carrier can be modulated by a sine wave, and generate a large number of sidebands. Chowning has commented that he:

> …could generate a whole range of sounds which done by other means demanded much more powerful and extensive tools. If you want to have a sound that has, say, 50 harmonics, you have to have 50 oscillators. And I was using two oscillators to get something that was very similar. [92]

Chowning's comments demonstrate the power of FM synthesis. The main difference between FM and either AM or RM is the number of sidebands. The sidebands are generated using the formula for sum and difference tones, by expanding the formula: C, C+M, C+(M*2), C+(M*3), etc, and C-M, C-(M*2), C-(M*3) and so on. If the carrier and

[90] Roads and others, 221-224.

[91] Ibid., 216-221.

[92] John Chowning, "FM is a universe of possibilities with a lot of surprises." *Yamaha magazine advertisement*, 1987; quoted in Curtis Roads John Strawn, Curtis Abbott, John Gordon, and Philip Greenspun. *The Computer Music Tutorial*, (Cambridge, Massachusetts and London, England: The MIT Press, 1996), 226.

modulator are in a simple ratio, such as 4:1, harmonic spectra result. Inharmonic spectra result if the carrier and modulator are in a ratio such as 8:2.1.

Frequency modulation has one other important parameter, the modulation index, which indicates the depth of vibrato. The modulation index controls the number of sidebands. It is calculated with this formula, $I = D/M$.[93] If the index is increased from 1 to 2, then the amount of frequency deviation will rise as well. If the modulator (M) is 100Hz, and the deviation (D) is 100Hz, then $I = 1$. As the index number increases, the presence of the carrier frequency diminishes, but the number of significant sideband pairs increase, usually $I+1$.[94] Generally speaking, many FM instruments are built with a varying, rather than constant, index,[95] so that the number of sidebands dramatically change the timbre of the sound. As the sidebands increase in volume, there is a decrease in the volume of the carrier.

FM synthesis is capable of producing complex spectra from simple means. The example below shows the dynamically changing spectra produced when changing the index from 1 to 4. Note that the pitches have been rounded off to the nearest quarter-tone. If the synthesis were to be carried out on a computer in a program like Csound, the rounding off would not be necessary. Also, note the diagram represents 'snapshots' of the sound, and the actual sound would be a gradual change from 4 to 1 if the sound were designed to do so.[96]

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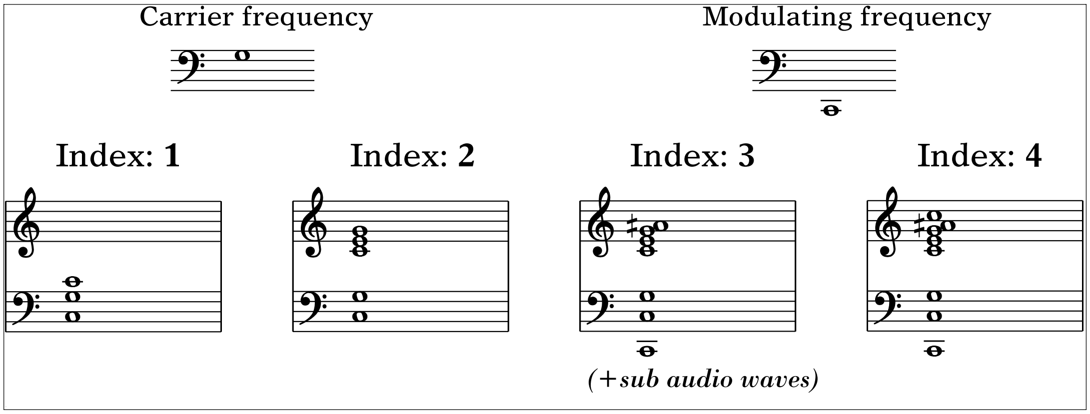
[93] Where **I** is the index of modulation, **M** is the modulating frequency, and **D** is the peak frequency deviation from the carrier: More clearly, the value of D is determined by the index (I) multiplied by the frequency (M). The programmer often specifies the value of I, and D is part of the resulting sound.

[94] Roads and others, 229-230.

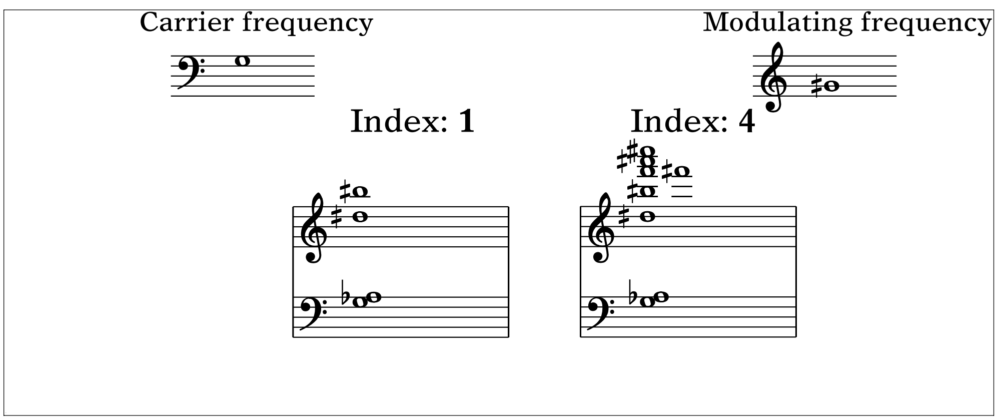
[95] See Gather, 90-106; Roads and others, 234; and Chowning "Synthesis of Complex Audio Spectra," 20, for examples.

[96] Note that the carrier and modulating frequencies are sine waves. If one or both signals were composed of complex waveforms, there would be more overtones.



Example 1-10 Frequency modulation expressed in musical notation.

The spectrum produced in Example 1-10 closely resembles the harmonic series. If the modulating frequency were not in a simple ratio[97], such as those found when using microtones, an inharmonic spectrum will result. Example 1-11 shows the result of such a procedure.



Example 1-11 Inharmonic frequency modulation.

The musical implications of modulating synthesis were astounding for the spectral composers, since the timbres produced by FM, AM, or RM provide the composer with a whole new palette of orchestral sounds. If orchestral (or chamber) music is combined with tape music utilizing these techniques, for instance, the orchestra can imitate the tape by producing an orchestral FM chord. This is exactly what happens in Désintégrations, as well as Murail's *Gondwana*. Grisey uses RM in several of his pieces, including *Partiels* and *Modulations*.[98] The latter work is particularly interesting, since the work does not contain an electronic tape part. The RM chords in the chamber ensemble are not used to imitate or blend with an electronic tape part, but to invoke the sounds found in electronic music. It is as if Grisey was trying to create an electronic piece without the use of electronics.

In general, the composer of electronic (or computer) music spends a great deal of time examining the microstructure of sonic events. The deconstruction of a sound often reveals that it is a composite of many different frequencies and timbres. The sub-timbres, which may or may not be overtones,[99] have their own envelopes, so that the relative amplitudes of the frequencies are constantly changing. A composer could easily apply these discoveries to orchestration as well as to harmonic evolution. Many composers have acknowledged the impact of the electronic studio on their musical thinking, especially their orchestration. The techniques of electronic music, as well as the microstructure of sound, have had a significant influence on spectral music. Most of the harmonic motion in a spectral work is derived from the time-varying processes found in electronic music.

IRCAM'S Influence

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[97] The ratio of carrier to modulator in Example 1-10 is approximately 3:1.

[98] Françoise Rose, "Introduction to the pitch organization of French spectral music," *Perspectives of New Music* 34/2 (Summer 1996), 6-39.

[99] The attack portion of a flute, for instance, contains many non-harmonic frequencies.

Certainly one of the most important influences on the spectral composers was the formation of IRCAM in the 1970s. The main focus of the institution was (and remains) the development of electronic music tools, both software and hardware. Guiseppe di Giugno developed the 4X computer in the late 1970s, "…an extremely rapid computer specializing in the production and manipulation of sound, and can synthesize or transform any sound in 'real-time'."[100] It was prominently featured in Boulez's *Répons.*[101]

IRCAM was not alone in computer music research. Actually, most of the early work in computer music was done in the United States, specifically at Bell Telephone Laboratories. Max Matthews is largely credited with creating the Music *N* Languages (Music V was the most versatile), which forms the basis for software synthesis programs in use today (Csound, Cmusic, and Common Lisp Music).[102] Risset's aforementioned *Introductory Catalog* was developed while Risset was working with Matthews at Bell Labs.[103] In the 1980s, the Cmusic program was developed at UCSD, Cmix was created at Princeton, and MIT's Csound emerged as the standard software synthesis language.[104] There are several significant research centers in the United States, notably CCRMA at Stanford University,[105] the University of Illinois,[106] and the Columbia-Princeton Electronic Music Center.[107] All of these centers had an influence on the early development of IRCAM,

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[100] Andrew Gerzso, "Reflections on Répons," *Contemporary Music Review*, 1 (1984), 24.

[101] See Dominique Jameux, "Boulez and the 'machine'," *Contemporary Music Review*, 1(1984), 11-24; also Gerzso.

[102] Roads and others, 89-90. Max Mathew's book *The Technology of Computer Music* (Cambridge, Massachusetts: The MIT Press, 1969) is worth mentioning here, since it was an enormously influential work which describes the Music V language.

[103] Ibid., 245.

[104] Ibid., 789-90.

[105] F.R. Moore, *Elements of Computer Music* (Englewood Cliffs: Prentice Hall, 1990), 400.

[106] Roads and others, 848.

[107] Ibid., 666.

and the research of these centers certainly had an impact on the music produced at IRCAM.[108]

A significant feature of IRCAM is its close relationship with the Ensemble InterContemporain. Under the direction of Pierre Boulez, the Ensemble is entirely dedicated to contemporary music, actively commissioning new works from a variety of composers. Because IRCAM is also concerned with the integration of electronic and acoustic music, the musicians of the Ensemble have made themselves available for numerous tasks, such as acoustic experiments as well as research into extended instrumental techniques. Many of the major spectral works came from this collaboration, including *Désintégrations*.[109]

In more recent years, the proliferation of personal computers has dramatically changed the production of electronic music. In previous years, a composer had to physically go to an institution where a computer music facility was housed. Quite often, the facility had a computer workstation that was tied into a mainframe computer. The work was often written in a program like Music V, Cmusic, or Csound. These programs required the user to have an in-depth knowledge of programming techniques. Actually, the composer had to write the computer portion of the work in the form of a program[110] which would be manually typed and compiled, a process that could take months.[111] Recent

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[108] Tod Machover, "A view of music at IRCAM," *Contemporary Music Review*, 1(1984), 1-10; see also Dominique Jameux, *Pierre Boulez*, trans. Susan Bradshaw (Cambridge, Massachusetts: Harvard University Press, 1991), 186-210; Joan Peyser, *To Boulez and Beyond: Music in Europe since "The Rite of Spring"* (New York: Billboard Books, 1999), 343-348.

[109] Machover, 1-10.

[110] In order to create a musical composition in one of these languages, the user needs to create *instruments* (such as those found in Gather), and a *score* (in the form of a notelist). The notelist is a text-based representation of the parameters that shape a given sound. Generally, the notelist invokes the instruments to start the sound at a specific time, using a specific frequency, at a specific volume, and to hold the note for a specific duration. This process needs to be repeated for each note in the work. The notelists can be extremely long.

[111] Csound is the most recent of these programs. Although it is based on the same architecture as Cmusic and Music V, there are a number of programs that will generate the notelist, such as John Rahn's "Lisp Kernel." In the Lisp Kernel, the composer creates a program in Lisp that specifies some general parameters, and the program creates the notelist, which is then compiled in the normal manner.

programs make use of mouse-driven graphic interfaces that are much easier to use.[112] With the development of faster personal computers with huge storage capacities, the heretofore time-consuming process of electronic music composition has been cut down dramatically.

IRCAM's focus in the last few years has been the development of programs to be used on personal computers. The programs they have developed include software designed to aid in the composition process (programs such as PatchWork and OpenMusic), sound synthesis (Chant, AudioSculpt, Diphone, and Modalys), and programs for live interaction between the performer and the computer (jMax and Spat). All of these programs make use of a graphic user interface and are extremely fast.[113] The time between conception and realization of an electronic work has therefore become much shorter.

Other influences on spectral music

There are several other possible influences on spectral music. Grisey has stated that the prevailing attitude of the younger European composers was that when Schoenberg and Stravinsky left Europe (in the late 1930s), they took the whole tradition of European music with them. There was little sense in continuing the aesthetic of the 19th century, and the 1950s avant-garde was not a path they wished to follow. Grisey and others felt that serialism produced a music that was lacking in focus, and "harmonically gray."[114] Therefore, spectral music may be seen as a reaction against the music of its immediate past. Rather than simply rejecting this music and reverting to a pre-Schoenberg state (as the American Neo-Romantics), the spectral composers looked at the increased awareness of timbre in music and decided to make that the basis for their music.

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[112] Roads and others, 659-852 provides an in-depth, historical survey of the development of the user interface in computer music.

[113] "Forum IRCAM: Computer Aided Composition, Real-Time Interaction, Sound Design," published brochure, available from the author.

[114] Grisey, conversation with the author.

Spectral music's influences range from the musical to the technological. The musical sphere may be viewed as an increased awareness of the role of timbre and texture as a shaping force in music. Spectral composers are particularly interested in the precise control of timbre. The tendencies started by Debussy culminate in the fusion of timbre and harmony in the works of the spectral composers.

Technological advances during the last century were a secondary influence on spectral composers. With the advent of computer based spectral analysis and synthesis, composers were able to quantify spectra in a precise manner. Eventually, the composers were able to reproduce complex spectra, and translate the results into musical notation; in the 1970s, however, much of the calculation was done by hand. The rise of powerful personal computers made it possible to do these mathematical operations much more efficiently. IRCAM's role cannot be understated in this realm, for its stated purpose is to bring together technological and musical research. Without the depth of technological research, spectral music may have vanished soon after it appeared the music considered a limited genre that required a tremendous amount of labor on the part of the composer.