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Electronic Contingencies: Goeyvaerts's Sine Wave Music and the Ideal of Perfect Sound

Melle Jan Kromhout

We were taught that the world could be described and even explained, by means of simple answers to intelligent questions. That in its essence the world was inert and dead, governed by fairly simple laws that needed to be explained and made public—if possible with the aid of diagrams.

Olga Tokarczuk, *Flights*¹

Looking at two electronic compositions, written by Belgian composer Karel Goeyvaerts in the early 1950s, this chapter explores the way in which sound technology in general—and electronic music in particular—simultaneously inspired ideas of sonic purity, total perfection, and absolute transparency, while also confronting composers and musicians with the inevitable limitations of technological mediation. By striving in vain for ideal electronic sounds produced without the interfering influence of a medium, Goeyvaerts was confronted with these limits of mediation. Despite or maybe even because of this failure of his idealist aspirations, I argue however, Goeyvaerts's compositions pointed the way toward the musical potential of electronic sound media.

At first sight, sound media seem to have allowed ever greater control over acoustic phenomena. Goeyvaerts's compositions show, however, that the physical processes that take place *inside* the black box—whether analog or digital—always maintain a level of contingency that escapes such control. Despite their promise of greater control, this fundamental contingency inherent to all media technological operations highlights the agency of the medium *itself* in shaping the sounds it (re)produces. Rather than the “imperfection” of these processes and sounds, this mediatic contingency emphasizes that perfection, purity, and transparency are ideals that we strive for—long for even—but that will never be attained. It thereby shows that

¹ Olga Tokarczuk, *Flights*, trans. Jennifer Croft (New York: Penguin, 2018).

precisely this supposed “imperfection” (or their fundamental inability to achieve ideal purity) made media technologies into endless reservoirs of sonic and musical creativity.

Striving for the Perfect Tone

At the 1951 instalment of the famous Summer Course for New Music in Darmstadt, led by Theodor Adorno, Karel Goeyvaerts first met his German colleague Karlheinz Stockhausen. The latter was so impressed by Goeyvaerts’s work that he quickly went on to declare that “from now on,” he would “accept only Karel Goeyvaerts as my teacher in composition.”² Throughout the first half of the 1950s, the two composers kept a busy correspondence in which they discussed, among other things, the musical foundations, aesthetic implications, and formal requirements of the emerging compositional principle called “total serialism.”³ This principle extended upon Arnold Schoenberg’s prewar twelve-tone system, which had abandoned the classical principles of tonal harmony by introducing “rows” or “series” of pitches that made each of the twelve tones in the Western diatonic scale equally important. Postwar *total* serialism strived for the serialization and rationalization of *all* musical parameters: not just pitch but duration, volume, meter, and, significantly, the complex inner structure of sound that is usually called “timbre” or “sound color” as well.

Over the course of their correspondence, Stockhausen and Goeyvaerts came to the conclusion that the realization of this desired control over every musical parameter required, as Stockhausen explained two decades later, the creation of “pure, controllable sounds without the subjective emotional influence of ‘interpreters.’”⁴ In other words, to gain absolute control over the basic sound material, the composer had to create this material using electronic devices. Electronic musical instruments had been around since at least the late nineteenth century, and the earliest report of electronically produced tones, or “galvanic music,” even dates back to the 1830s.⁵ Furthermore, already in

² Mark Delaere, “Karel Goeyvaerts: A Belgian Pioneer of Serial, Electronic and Minimal Music,” *Tempo* 195 (1996): 2.

³ Stockhausen’s letters are reproduced in Herman Sabbe, *Karlheinz Stockhausen: ... Wie die Zeit verging ...* (Munich: Texte + Kritik, 1981). Goeyvaerts’s side of the correspondence is reproduced in Karel Goeyvaerts, *Selbstlose Musik. Texte, Briefe, Gespräche*, ed. Mark Delaere (Cologne: Musik Texte, 2010).

⁴ Karlheinz Stockhausen, “The Origins of Electronic Music,” *Musical Times* 112, no. 1541 (1971): 649.

⁵ Tara Rodgers, “Synthesis,” in *Keywords in Sound*, ed. David Novak (Durham, NC: Duke University Press, 2015), 208–21. Rodgers refers to “The Production of Galvanic Music” by C. G. Page, which was published in 1837. Some well-known early electronic instruments

1936, composer Edgar Varèse predicted that the possibilities of sound media could ultimately allow for the creation of “an entirely new magic of sound” that would usher in what he called the “liberation of sound.”⁶ Only after the Second World War, however, fully controllable electronic sound production became possible.

Especially the new and more advanced magnetic tape recorder that had been developed in Germany during the war and was confiscated and brought back to the UK and United States by the Allied forces in 1945 allowed for a big leap in sonic possibilities. Along with other recently developed sound and communication technologies, these possibilities were explored in the first proper music studios, which were established in Paris in the late 1940s and in Cologne in the early 1950s. In the Paris studio, composers Pierre Schaeffer and Pierre Henry and their team developed a type of music called “musique concrète,” which uses prerecorded and subsequently manipulated sounds (effectively “sound samples” *avant-la-lettre*) for the creation of abstract, electroacoustic compositions. Stockhausen worked in the Paris studio for a few months in 1952, and his letters to Goeysvaerts reported back on the extremely time-consuming and often tedious procedures that went into the production of musically useful sounds.

Stockhausen and Goeysvaerts, however, were not particularly interested in the aesthetic paradigms of *musique concrète* (using tape machines to record and manipulate preexisting sounds), which they found too imprecise and musically un compelling. Stockhausen disdainfully called it “a capitulation before the undefined, a terribly dilettantish gamble, uncontrollable improvisation.”⁷ Instead, as Goeysvaerts describes, because “the possibilities that had been established thus far” with regard to electronic sound production collided with the musical ideas of total serialism that they were developing around that same time, they were more interested in producing entirely new sounds altogether.⁸ Among the most radical outcomes of this collision between electronic sound media and total serialism are two compositions by Goeysvaerts from 1952 and 1953: *Nr. 4 met dode tonen* (“N°. 4 with dead tones”) and *Nr. 5 met zuivere tonen* (“N°. 5 with pure tones”). The scores for these pieces, which consist of instructions for the technological production

include the “telharmonium,” invented in 1897, the “sphaerophon,” introduced in 1921, the “theremin” and “ondes martenot,” both invented in 1928, and the “trautonium,” invented in 1929.

⁶ Edgar Varèse and Chou Wen-Chung, “The Liberation of Sound,” *Perspectives of New Music* 5, no. 1 (1966): 12, 14.

⁷ Stockhausen in Richard Toop, “Stockhausen and the Sine-Wave: The Story of an Ambiguous Relationship,” *Musical Quarterly* 65, no. 3 (1979): 388.

⁸ Goeysvaerts, *Selbstlose Musik*, 166. All translations of otherwise untranslated sources are my own.

of specific sounds and a schematic visualization of their compositional organization, count as one of the earliest examples of precomposed electronic music.

For the first piece, *Nº. 4 with dead tones*, which would not actually be realized until several decades later, Goeyvaerts prescribes the production of the most static sounds imaginable. Although, in terms of their frequency composition, these sounds were allowed to be spectrally complex (which means they can be quite dense), the, often minute, changes that shape all natural sounds as they unfold in time should be minimalized as much as possible.⁹ In light of this, Goeyvaerts even asked Stockhausen whether it would be possible to record sound on a tape recorder “in the ‘pause position,’ i.e. onto an infinitesimally small area of tape.”¹⁰ This technically somewhat naive question reveals that Goeyvaerts strived for sounds with no temporal development whatsoever—entirely static, periodic, indeed “dead” tones that do not change over the course of their temporal unfolding. As they are supposed to have “absolutely no unpredictable ‘inner life,’” Richard Toop concludes, the dead tones of *Nº. 4* are intended to be “identical at any moment in time, and therefore detached from time itself.”¹¹

While working on *Nº. 4*, Goeyvaerts still referred to the sonic elements that could be used as basic material for these essentially timeless sounds as “sound atoms.”¹² However, a few months later, during a visit to a radio station in Brussels in March 1953, he discovered that it was actually possible to electronically generate a type of sound that the director of the studio in Cologne, Herbert Eimert, would later call a “pure element.”¹³ This is a “sine wave”—it consists of one single frequency, without any overtones, and thus without any distinguishable sound color of itself. Although true (absolutely pure) sine waves, as I will come to explain, are physically impossible, they can be electronically approximated. As such, they seemingly constituted a logical endpoint of the serialist search for entirely isolated tones that allow full control over all musical parameters.¹⁴ Not long after learning of their

⁹ As Goeyvaerts describes in his letter to Stockhausen of November 12, 1952: “I only use homogenous tones with a constant spectrum, which have no relation to each other, like corpses lying next to one another. ... All I ask is that they are homogeneous and very different from each other, to make sure one can never even have the illusion of a relation or mixture.” Goeyvaerts, *Selbstlose Musik*, 333.

¹⁰ Goeyvaerts in Toop, “Stockhausen,” 387.

¹¹ Toop, “Stockhausen,” 386.

¹² Sabbe, *Karlheinz Stockhausen*, 14.

¹³ Herbert Eimert, “Der Sinus-Ton,” *Melos* 21 (1954): 168.

¹⁴ M. Josephine Grant, *Serial Music, Serial Aesthetics: Compositional Theory in Post-War Europe* (Cambridge: Cambridge University Press, 2001), 58–60.

existence, Goeyvaerts therefore began contemplating a new composition: *N° 5 with pure tones*.

For *N° 5*, which, unlike *N° 4*, was sonically realized by the composer himself at the time of its composition, Goeyvaerts used sine waves to extend the serialist order to the composition of the sound spectra themselves. It was no longer enough to suppress the temporal development of the sounds as much as possible. To realize the desired “ultimate fixation and standing quality of sound,” the sounds of *N° 5* would have to be built from the ground up, using electronically produced sine waves.¹⁵ The composer thereby expands a rigid numerical order over every aspect of the compositional material: serializing pitch, duration, rhythm, volume, *and* sound color (or spectral identity)—separately *and* in relation to each other.¹⁶ Furthermore, as had been the case with *N° 4*, the piece is structurally symmetrical or palindromic: it turns around at its halfway point and closes in on itself at the end. On paper, *N° 5* thereby becomes an entirely closed, almost algorithmic procedure that is supposed to be sonically identical to itself at all times and with each play.¹⁷

Based on the latest insights and advances in physical acoustics and media technology, *N° 4 with dead tones* and *N° 5 with pure tones* thereby constitute a radical attempt to wield total compositional control over the material basis of sound.¹⁸ Despite this striving for absolute sonic purity, however, Goeyvaerts was disappointed with the sounding results:

To begin with there was a lot of crackle on the tape as a result of the repeated playovers. Then one could clearly hear the different component tones, while I had hoped that by adding and subtracting component tones the tones themselves would sound more bright or more muffled. That a composition with sinus tones, at that time the only ones I would

¹⁵ Herman Sabbe, “A Paradigm of ‘Absolute Music’: Goeyvaerts’s *N° 4* as ‘Numerus Sonorus,’” *Revue Belge de Musicologie/Belgisch Tijdschrift voor Muziekwetenschap* 59 (2005): 243.

¹⁶ Regarding this relation between sonic parameters, Decroupet and Ungeheuer, for example, write that “in the first section of Goeyvaerts’ score, the ratio between pitches (measured in hertz) and durations (in cm) is characterized by a ratio of 10:1 between the highest frequency and the longest duration.” Pascal Decroupet and Elena Ungeheuer, “Karel Goeyvaerts und die Serielle Tonbandmusik,” *Revue Belge de Musicologie/Belgisch Tijdschrift voor Muziekwetenschap* 48 (1994): 113.

¹⁷ Sabbe, “Paradigm,” 243.

¹⁸ Sabbe describes *N° 4* and *N° 5* as “the most radical pretension of totality and positivity ever.” Sabbe, “Paradigm,” 244. Delaere writes of “the most relentless and authentic embodiment of artistic purity in European art music of the 1950s.” Delaere, “Karel Goeyvaerts,” 3.

contemplate using, was so disappointing was something I found hard to accept. As yet absolute certainty lay outside my grasp.¹⁹

Although the latest technical advances had seemingly promised “absolute certainty” and the fulfilment of Goeyvaerts’s idealistic strivings, the physical limitations of the technological operations that were necessary to produce these electronic sounds ensured that the sonic end result remained far removed from the certainty and purity he envisioned. Instead of the only logical, or even necessary way forward for Western music, total serialism in its strictest form, and Goeyvaerts’s electronic version of it in particular, proved untenable. M. Josephine Grant therefore tellingly describes *Nº. 5* as a “perfect example of the imperfection of perfection.”²⁰

And yet, instead of an example of *failed* perfection or the *failed* attempt to achieve absolute control, I want to argue that it is exactly this supposed “imperfection” that makes these pieces interesting. Ideals of purity and harmony have defined the theory and philosophy of Western music for centuries. In contrast to these ideals, which Caleb Kelly, in his contribution to this volume, describes as the “explicit goal of music, both in the physical form of its instruments and in the exactitude of its performance,” the technological “imperfections” that mark Goeyvaerts’s compositions focus our attention on the fact that transience, chaos, noise, and distortion are ontologically fundamental.

Imperfection, in this case, is not (or no longer) understood as a failure, a break, a glitch, or an error, in comparison to which the constructedness of realism or the shortcomings of representational transparency are revealed, as Mieke Bal theorizes the notion elsewhere in this collection. Rather does it act as a reminder that realism, transparency, and purity are always impossible to begin with. To get away from the normative perfect/imperfect dichotomy, it might therefore be more productive to define this absence of ideal *perfection* (or purity, control, transparency) not as *imperfection* but as inherent and fundamental *contingency*.

The acknowledgment of this contingency constitutes a step toward a different attitude toward the musical potential of electronic sound media: away from positivist ideals of perfect fidelity and pure sound, and toward a more complex and nuanced relationship with the unruly nature of both sound and media. Because the operations of sound media always escape our authorial

¹⁹ Karel Goeyvaerts, “Paris-Darmstadt 1947–1956: Excerpt from the Autobiographical Portrait,” *Revue Belge de Musicologie/Belgisch Tijdschrift voor Muziekwetenschap* 48 (1994): 51.

²⁰ Grant, *Serial Music*, 65.

grasp, they forge a sense of autonomous agency that is not closed, finished, or “perfect” but open, unpredictable, and contingent. The significance of this observation becomes all the more apparent when one looks beyond the specific context of postwar avant-garde music to consider Goeysvaerts’s sine wave music as part of the interwoven history of music, acoustics, and media from the mid-nineteenth century onward. More specifically, such a closer look at the history of acoustics not only helps to understand why Goeysvaerts and Stockhausen became interested in sine waves in the first place but also why they quickly abandoned it.

A Short History of Sine Waves

The equivalence between the geometric sine function and the vibrations of a musical string was first suggested by Dutch physicist, mathematician, and astronomer Christiaan Huygens in 1673, and further developed by (independently from each other) English mathematician Brook Taylor and French acoustician Joseph Sauveur in 1713.²¹ The debate about the mathematical validity and physical significance of this representation continued throughout the eighteenth-century dispute on the problem of the vibrating string, most significantly among mathematicians d’Alembert, Euler, Lagrange, and Daniel Bernoulli, who all made important contributions to mathematical and physical theory. In the 1740s, Bernoulli was the first to suggest the possibility that the vibrations of a string can be represented by *series* of superpositioned sine waves. This hypothesis would only gain more general acceptance after Joseph Fourier in 1822 published the analytical method that would later carry his name.

Fourier, however, did not introduce his theorem in the context of acoustics, but as part of his analytical theory of heat. In simple terms, Fourier Analysis mathematically represents a complex function (like the propagation of heat through a solid,²² a sound event, an electrical impulse, the course of planetary objects, or tidal movements) as a series of superpositioned “simple states.” With the use of Fourier’s method, one can therefore transform a compound signal as it develops *over time* into a timeless representation of its organization *in space*. In the case of heat propagation, for instance, it represents the temperature of an object at points closer or further removed

²¹ Olivier Darrigol, “The Acoustic Origins of Harmonic Analysis,” *Archive for History of Exact Sciences* 61, no. 4 (2007): 351–2.

²² Jean Baptiste Joseph Fourier, *The Analytical Theory of Heat*, trans. Alexander Freeman (Cambridge: Cambridge University Press, 2009), doi:<https://doi.org/10.1017/CBO9780511693205>.

from the heat source; and in the case of sound, it represents a frequency spectrum as a series of individual sinusoids, or sine waves.

Crucially, however, this nineteenth-century representation of sound as a series of sine waves (or partial tones) only applies to entirely periodic sounds with no temporal development, that is, to idealized sound events of infinite duration and unchanging spectral composition. More advanced forms of Fourier's theorem, which have subsequently been developed, can also be applied to nonperiodic phenomena. Even in these cases, however, all information about the temporal development of the signal (or its change over time) is effectively lost. Fourier Analysis, in short, produces an entirely static, unchangeable, a-temporal representation of sound waves.²³

After the publication of Fourier's treatise, it took two more decades before Georg Simon Ohm applied his theorem to the analysis of sound. After publishing the article with the catchy title "On the Definition of a Tone with the Associated Theory of the Siren and Similar Sound Producing Devices" (1843), however, Ohm received heavy criticism by acoustician August Seebeck, whose experiments with a mechanical siren had inspired Ohm's analysis in the first place.²⁴ Because of this controversy, it took more than a decade until Hermann von Helmholtz corroborated and further developed Ohm's findings in his highly influential work on sound and hearing, which he began in the mid-1850s and concluded with the seminal book *On the Sensations of Tone as a Physiological Basis for the Theory of Music* (1863).²⁵ By "hearing out" what he called "simple tones" with the help of so-called acoustic resonators, and construing artificial sound spectra with his tuning fork synthesizer (the first of its kind), Helmholtz provided empirical proof for Ohm's mathematical analysis. Bridging the gap between theory and observation, he turned the mathematical sine function into an acoustical object of sorts.

From the late seventeenth century until the mid-nineteenth century, then, the concept of the sine wave developed from a mathematical function, via its graphical representation in the context of the analysis of the representation

²³ Over the course of the twentieth and twenty-first centuries, many strategies to overcome this a-temporality of Fourier analysis have been developed. On the most basic level, one can, for instance, analyze the frequency spectrum of many consecutive bits of time and plot these on a temporal axis. All time-frequency analysis, however, requires a compromise between spectral detail and temporal accuracy.

²⁴ Georg Simon Ohm, "On the Definition of a Tone with the Associated Theory of the Siren and Similar Sound Producing Devices," in *Acoustics: Historical and Philosophical Development*, ed. R. B. Lindsay, 242–7 (Stroudsburg: Dowden, Hutchinson & Ross, 1972).

²⁵ Hermann von Helmholtz, *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, trans. Alexander Ellis (Cambridge: Cambridge University Press, 2012), doi:<https://doi.org/10.1017/CBO9780511701801>.

of a vibrating string, into a semi-acoustical object in the work of Ohm and ultimately Helmholtz. This epistemological status in-between concept and object already becomes apparent from the introduction to Fourier's treatise, in which he writes that the universal language of mathematical analysis—to which he himself made an important, but at the time still controversial, contribution—could “supplement the shortness of life and the imperfection of the senses.”²⁶ It thereby shows, he continues, “the unity and simplicity of the plan of the universe” and the “unchangeable order which presides over all natural causes.”²⁷ For Fourier, the representation of physical phenomena through mathematical analysis reveals an order and simplicity that our senses can never perceive. It allows phenomena that appear to be nonperiodic, transient, complex, and fundamentally entangled, to be broken up, disentangled, and thus understood and explained—not with our imperfect sensory apparatus but with the help of the perfect, timeless operations of mathematical analysis.

Ohm, writing two decades later, voices a similar belief in the simplicity and order of nature, and the power of mathematical analysis to unravel its intricacies. To defend his use of Fourier analysis and its emphasis on the sinusoidal shape of elementary tones, he writes that “in the explanation of a natural phenomenon no other causes should be assumed than are both necessary and sufficient.”²⁸ Ohm was originally trained as a mathematician, and highly influenced by Fourier's innovative style of mathematical physics, which he already emulated in his famous work on electricity in the 1820s. However, unlike most other early and mid-nineteenth-century physicists dealing with sound, Ohm was rather unconcerned with musical questions, and not even all that interested in acoustics as such. Instead, he approached the problem of the definition of a tone primarily from a mathematical viewpoint.²⁹

What unites Fourier and Ohm, then, is their role as transitional figures in the nineteenth-century development of mathematical physics. Their work marks a shift in scientific methodology: from a type of research that primarily developed physical theories on the basis of qualitative experimental results and direct sensory observation, toward a form of theoretical physics in which hypotheses are developed on the basis of increasingly complex mathematics. These hypotheses can subsequently be verified or falsified by assessing quantitative experimental results that not seldom surpass the capabilities of

²⁶ Fourier, *Analytical Theory*, 8.

²⁷ Ibid.

²⁸ Ohm, “Definition,” 245.

²⁹ Melle Jan Kromhout, “The Unmusical Ear: Georg Simon Ohm and the Mathematical Analysis of Sound,” *Isis* 111, no. 3 (2020): 471–492.

human sensory observation.³⁰ This novel use of mathematical modeling as a primary epistemological tool, however, requires a fundamental belief in the correspondence between the symbolic representations produced by the analysis and the physical phenomena under investigation.

In the case of Ohm's application of Fourier analysis to study sound waves, this belief in the representational power of the mathematical model is based on three conceptual assertions. First, that sounds are indeed composed of a series of elemental frequencies. Second, that these frequencies can be represented by the mathematical concept of simple sinusoidal motion. Third, that each of these elemental frequencies constitutes a real and physically present "partial" sound in and of itself. As such, only after Bernoulli's hypothesis in the mid-eighteenth century, Fourier's analytical method of 1822, Ohm's acoustic law of 1843, and Helmholtz's experimental verification of it in 1863, could the sine wave be considered an "elemental sound," or what Helmholtz calls a "simple tone."

Still, as Alexandra Hui writes, "idealization and ideal types were central to [Helmholtz's] scientific work" as well.³¹ Not unlike Fourier and Ohm, Helmholtz also "maintained a larger classicist goal of revealing universal truths."³² Hence, the natural order and universal truth suggested by Fourier's analytical method perfectly suited his search for ideal forms and belief in the inherent order of the natural world.³³ As for his musical preferences, Helmholtz was strongly committed to nineteenth-century German aesthetic ideals that valued the expression of a musical "idea" expressed through abstract sounding forms above all else. In this context as well, the mathematical emphasis on strictly periodic sounds with mostly harmonic overtone structures (sounds that Helmholtz tellingly calls *musical tones*) fits the long-standing Western music theoretical separation between (periodic, harmonious, ordered) music and (nonperiodic, cacophonous, chaotic) noise. Helmholtz's acoustic analysis thereby supports an understanding of periodic, harmonic, *musical* sound as an expression of a well-ordered world.

Hence, with Helmholtz's groundbreaking and influential model of sound and hearing, the fundamental concept of the sine wave (as part of his spectral model of sound, based on the mathematical operations of Fourier analysis)

³⁰ Kenneth Caneva, "From Galvanism to Electrodynamics: The Transformation of German Physics and Its Social Context," *Historical Studies in the Physical Sciences* 9 (1978): 66.

³¹ Alexandra Hui, *The Psychophysical Ear: Musical Experiments, Experimental Sounds, 1840–1910*, (Cambridge, MA: MIT Press, 2013), 61.

³² Hui, *Psychophysical Ear*, 61.

³³ M. Norton Wise, "What's in a Line?," in *Cultures and Politics of Research from the Early Modern Period to the Age of Extreme*. Vol. 1: *Science as Cultural Practice*, ed. Moritz Epple and Claus Zittel (Berlin: Akademie Verlag, 2010), 98.

became a peculiar, double-sided figure. It emerged at the crossroad of two scientific paradigms, which Lorraine Daston and Peter Galison call “truth-to-nature” and “objectivity.”³⁴ Around the mid-nineteenth century, the older paradigm, striving for “true” but idealized representations of nature, gave way to an “objective” paradigm that took the detailed, contingent, and not seldom chaotic complexity of physical processes into account.

Whereas Helmholtz’s experimental practice very much fitted this newer approach, and the operations of Fourier analysis traded ideals of absolute representation for the embrace of infinite mathematical approximation, the figure of the sine waves also very much stands as a more universal representational ideal. On the one hand, the sine wave is the pinnacle of an idealist drive toward clarity: a purely periodic, entirely symbolic representation of a fundamentally a-temporal sound. On the other hand, it constitutes one of the pillars of a materialist concept of sound: the basic element of physical sound waves that became crucially important for media technological sound processing.

The Agency of Sound Media

Musically, the consequences of this nineteenth-century scientific approach to sound really became apparent from the early twentieth century onward. In the case of Schoenberg, Julia Kursell for instance shows that, although he did probably not read Helmholtz’s work directly, his compositional principle of *Klangfarbenmelodie* (“sound color melody”) was conceptually indebted to the latter’s analysis of overtone series.³⁵ This “timbral” principle of organizing sound material, according to which “notes overlap, creating a smooth transition from one stable sound to the next,” in turn constituted an important step toward Schoenberg’s complete abandonment of tonal harmony and his development of twelve-tone composition.³⁶ With postwar total serialism, this idea of the controllable and analyzable musical parameter became all-encompassing. In fact, the notion of the “parameter” *as such* can be said to originate in the nineteenth-century mathematization of physical sound.³⁷ As the serialist ideal of complete compositional control over every

³⁴ Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Book, 2007), 42–5.

³⁵ Julia Kursell, “Experiments on Tone Color in Music and Acoustics: Helmholtz, Schoenberg, and *Klangfarbenmelodie*,” *Osiris* 28, no. 1 (2013): 210.

³⁶ Ibid.; Alfred Cramer, “Schoenberg’s *Klangfarbenmelodie*: A Principle of Early Atonal Harmony,” *Music Theory Spectrum* 24, no. 1 (2002): 1–34.

³⁷ Grant writes that the musical application of the mathematical concept of the “parameter” in the first half of the twentieth century was “probably influenced by Meyer-Eppler” (the future director of the studio in Cologne), but “he was not the first to use it in an acoustic

dimension of sound (pitch, duration, volume, timbre) presupposes the complete quantification of its physical properties into a clearly defined set of fully analyzable acoustical parameters, it relies on exactly the kind of analytical approach that nineteenth-century acoustics provided.

The elementary or “simple” tone generally called “sine wave” is arguably one of the quintessential figures of this development. Indeed, the crucial importance that Stockhausen and, especially, Goeyvaerts contributed to this “almighty basic material governing every sound phenomenon” showcases a duality that is reminiscent of the one between scientific materialism and philosophical idealism that marks Helmholtz’s spectral theory of sound.³⁸ On the one hand, electronic music in general and the use of sine waves in particular seemingly promise the complete objectivation of music based on the unambiguous analysis of the physical properties of sound itself. It thereby promises, as Herman Sabbe writes, “authorial control—total, objectified, and arbitrary—extending over and including the ‘persona’ of the author himself, a control aimed at the exclusion of emotional expression, the elimination of subjective intervention.”³⁹ On the other hand, this same approach also upholds the nineteenth-century formalist aesthetic of absolute music, which strives for some transcendental “truth,” which is neither material nor physical, but inherent to the musical *idea* that is expressed in the work of art itself.

Goeyvaerts’s idealist aesthetic therefore is, as Mark Delaere puts it, “both a rejection and an amplification of the aesthetics of Romanticism.”⁴⁰ The supposed acoustic purity of sine waves simultaneously does away with Romantic ideas of authorship and emotional expression, while simultaneously propagating the equally Romantic phantasma of the everlasting truth expressed by the musical work of art. To be fair, Goeyvaerts very much acknowledged this double-sidedness when, in his preparatory notes, he described the “dead tones” of *N°. 4* as idealized “sounds without corporeality,” but also added the words: “etiam peccata [and sins]. Our knowledge is conditioned by our sinful being.”⁴¹ The composer thereby implicitly acknowledges that pure spirituality and infinite perfection are fundamentally unattainable in our earthly domain. Furthermore, his remark underscores the fact that, for both Goeyvaerts and

context. This honour goes to [composer and music theorist, MK] Joseph Schillinger.” Grant, *Serial Music*, 62.

³⁸ Goeyvaerts, *Selbstlose Musik*, 166.

³⁹ Herman Sabbe, “Karel Goeyvaerts: More Than a Footnote in the Book of Music,” in *Rewriting Recent Music History: The Development of Early Serialism 1947–1957*, ed. Mark Delaere (Leuven: Peeters, 2011), 71.

⁴⁰ Delaere in Goeyvaerts, *Selbstlose Musik*, 12. This translation is from Martin Iddon, “Selbstlose Musik: Texte, Briefe, Gespräche by Karel Goeyvaerts,” *Notes* 69, no. 3 (2013): 532.

⁴¹ Sabbe, “Paradigm,” 244.

Stockhausen, the interest in sine waves was as much motivated by formalism as by religious dogma. It shows that the idea of sine wave music was not just a product of zealous formalism and the avant-gardism of the postwar “zero hour,” but just as much an expression of a profound belief in divine order, and the ancient idea of music as, in Toop’s words, an “image of the *harmonia mundi* and, indeed, the harmony of the universe.”⁴²

Seen from this perspective, the organizational principle behind total serialism, its complete abandonment of tonal harmony notwithstanding, still constitutes a continuation of the Western musical drive toward order, structure, harmony, and purity. Indeed, it is exactly this compositorial aesthetics of control, perfection, and harmonic order, which defined much of Western art music, that Ted Gioia positions against the improvisational “aesthetics of imperfection” as embodied by jazz.⁴³ In a similar move away from the aesthetics of perfection, I would argue that, in the case of Goeyvaerts’s sine wave music, the collision between total serialism and electronic sound media also offers a different perspective: it is not in the musical ideals that Goeyvaerts wanted to achieve, nor in the way in which these pieces live up to these ideals, but in the way in which they do not live up, *could never have lived up* to these ideals that they mark a significant moment in the history of music. Precisely because an electronically produced sine wave does *not* attain mathematical symbolic purity, and is always shaped by contingent mediatic processes, Goeyvaerts’s compositions highlight the way in which sounds produced by the channels of sound media inspired entirely new modes of musical production.

After spending many weeks of intensive studio labor on *Nº. 5*, Goeyvaerts was highly disappointed by the way his first proper sine wave composition sounded. As he recalls in the early 1990s, he considered the result “not very musical after all.”⁴⁴ Although the use of sine waves was supposed to produce the kind of heavenly clarity and perfect order suggested by Fourier’s analysis, the process of layering electronically produced simple tones on top of each other to produce new compound sounds meant that the materiality of the tape itself inevitably detracted from the desired purity, thereby redirecting the listener’s attention away from immaterial sound and absolute music toward the technological production and reproduction process itself.

In a way, it thereby reaffirms the criticism of the spectral representation of sound that was voiced from Ohm’s article in 1843 onward. At the time,

⁴² Toop, “Stockhausen,” 383.

⁴³ Ted Gioia, *The Imperfect Art: Reflections on Jazz and Modern Culture* (Stanford, CA: Stanford Alumni Association, 1988), 57.

⁴⁴ Goeyvaerts, *Selbstlose Musik*, 476.

Seebeck accused Ohm of ignoring audible evidence against his hypothesis and argued that an exclusive focus on sinusoids could not fully explain the perception of pitch.⁴⁵ Despite these concerns, Helmholtz sided unequivocally with Ohm and even argued that the ear *itself* performs some kind of Fourier analysis when processing complex waveforms. Partly because of his focus on periodic, “musical” sounds, Helmholtz thereby chose to ignore psychoacoustic evidence that would complicate his analytical model. This caused him to overemphasize the importance of Fourier’s theorem and the role of sine waves at the expense of other physical and psychoacoustic factors.⁴⁶

However, what Seebeck already suggested in 1843 would largely be confirmed over the course of the twentieth century. Nowadays, as Alain de Cheveigné writes, “the weight of evidence against [Helmholtz’s] theory as the sole explanation for pitch perception is ... overwhelming.”⁴⁷ As it turns out, the ear does not, or at least not only, function as a Fourier analyzer, because there is more to physical sound and the faculty of hearing than spectral composition. Within the context of the current argument, the most important limitation of a spectral model based on Fourier analysis is its disregard of temporal change. This led Helmholtz to overemphasize periodicity and regularity at the expense of a more nuanced reflection on the inherently transient nature of sound and, more specifically, on the short, transient, nonperiodic, and complex elements that shape affect sonic identity as well. As a result, Goeyvaerts, Stockhausen, and others discovered during their experiments with electronic music in the 1950s, what looks like a well-structured, closed, and elegant model turns out to be much more complex, stubborn, and difficult to control in physical reality.

“Though the sine tone is,” Grant writes, “physically, ‘pure,’ our hearing of it is not,” because “even apparently stationary sine tones are furnished with transients by the ear.”⁴⁸ Even without taking such psychoacoustic effects that prevent us from hearing stationary tones as such into account, however, an electronically generated sine wave is not even *physically* “pure” either. This purity only exists in the idealized realm of mathematical analysis, where

⁴⁵ For a concise overview of the debate between Ohm and Seebeck, see R. Steven Turner, “The Ohm-Seebeck Dispute, Hermann von Helmholtz, and the Origins of Physiological Acoustics,” *British Journal for the History of Science* 10, no. 1 (1977): 1–24.

⁴⁶ See for instance Eric J. Heller, *Why You Hear What You Hear: An Experiential Approach to Sound, Music, and Psychoacoustics* (Princeton, NJ: Princeton University Press, 2013), 444–5; Alain de Cheveigné, “Pitch Perception Models,” in *Pitch, Neural Coding and Perception*, ed. Christopher J. Plack, Andrew J. Oxenham, Richard R. Fay, and Arthur N. Popper (New York: Springer, 2005), 180–2.

⁴⁷ Cheveigné, “Pitch,” 181.

⁴⁸ Grant, *Serial Music*, 60.

it is contingent on the complete neglect of the temporal domain. Because, mathematically, a perfect sine wave is infinite by definition, an electronically generated and inherently finite sine wave cannot be absolutely pure. In technological reality, in which sounds do not only have a spatial (or spectral) dimension but take place in and change over time as well, sine waves only ever approximate but never attain the promised purity of their mathematical ideal. Instead, their technological production as sound always leaves behind material traces in the form of sonic artefacts.⁴⁹

This is why Goeysvaerts's idea to record on tape "in the pause position" is so telling: in his desire to capture absolute, infinitely static sounds that would remain unaffected by the medium used to produce and transmit them, he completely denies the necessity for both recorded sound and recording tape to *run* and thus extend over time. He denies, in short, the fundamental processual nature of both sound and the media technological operation.

Following what Yuriko Saito, in her chapter for this volume, calls "Francis Bacon's ... blueprint for technological advancement," by trying to exert complete control over the material properties of sound and media, Goeysvaerts's perfectionist aesthetics remains fixated on an idealist goal of "overcoming limitation nature places on us, such as inevitable vicissitude of material objects." However, exactly this "limitation nature places on us" (as human beings) limits the operations of the medium as well.

Whereas Goeysvaerts still vehemently defended the primacy of the sine tone in June 1953—even against accusations that it "physically hurts and makes one nervous"—Stockhausen already began to acknowledge these limitations of electronic sound production.⁵⁰ "Instead of allowing greater control and more transparency," he writes to Goeysvaerts

each loudspeaker is less transparent than an interpreter; each machine, with each generator even, each impulse: the uniqueness of each event, the unobjectifiable, unrepeatable, subjective "coincidence" remains. And I am content with that nowadays. The unexpected, the unresolved rest, the indefinable may always be around me and above me.⁵¹

⁴⁹ The fact that Fourier analysis only represents the spectral but not the temporal domain was addressed by physicist Dennis Gábor in Dennis Gábor, "Acoustical Quanta and the Theory of Hearing," *Nature* 159, no. 4044 (1947): 591–4. The musical consequences of this observation were extensively explored in the theoretical and musical work of composer Iannis Xenakis. Iannis Xenakis, *Formalized Music: Thought and Mathematics in Composition*, 2nd ed., trans. Christopher Butchers, G. H. Hopkins, John Challifour, and Sharon Kanach (Stuyvesant, NY: Pendragon Press, 1992).

⁵⁰ Goeysvaerts, *Selbstlose Musik*, 350.

⁵¹ Stockhausen in Sabbe, *Karlheinz Stockhausen*, 49.

By acknowledging the contingencies that are inherent to media technological operations, Stockhausen thereby marks the transition from the idealistic striving for absolute sonic perfection toward the embrace of the incidental and unpredictable nature of media technological operations. Due to their processual nature, media always affect the signals they process in unexpected and never entirely predictable ways. What happens inside the black box leaves a trace that is imprinted on the signals. Hence, what seems perfectly unambiguous on the idealist plane of Fourier analysis (endlessly oscillating, entirely pure sine waves) is less so in the physical realm of technological signals. In this realm, “the unexpected, the unresolved rest, the indefinable,” as Stockhausen calls it, can never be fully expelled, and “the unobjectifiable, unrepeatable, subjective ‘coincidence’” always remains.

Ultimately, Goeysvaerts also came to terms with the fact that what frustrated him with N°. 5 (the crackle on the tape and not fully integrated component tones) was the result of what Stockhausen acknowledges in the above quote: the process of mediation *itself* inevitably affects the sounds that are produced, causing unexpected, transient alterations either on the level of the physical signal itself or in our perception. These changes fundamentally negate the ideal, representational purity that Goeysvaerts initially sought. They thereby emphasize that, outside of the controlled setting of an acoustic laboratory, when the representational model of Fourier analysis is turned into physical sound it does not reveal a hidden natural order or divine harmony, but the inherent limitations of the model itself. After all, “on the microlevel of sounds, as on the microlevel of matter,” Grant writes, the absolutist, unchangeable perfection of the analytical model has never been there to begin with, and “approximation is the best we can achieve.”⁵² This “approximation,” however, should not be understood as a lack or a failure. Instead, it serves as a consistent reminder that, not unlike “the subjective emotional influence of ‘interpreters’” that Goeysvaerts and Stockhausen sought to overcome, the material agency of the medium *itself* (or what Saito, in her chapter for this volume, calls the “vicissitude of the material world”) can never be fully erased or completely controlled.

Hence, by 1955, four years after the Summer Course in Darmstadt where he and Stockhausen first met, Goeysvaerts also acknowledged that his quest for sonic purity had been doomed from the outset: “in the beginning,” he wrote, “I sought after a greater musical purity; today, I am confronted by an other sound material.”⁵³ This *other* sound material, he explains two years

⁵² Grant, *Serial Music*, 66.

⁵³ Karel Goeysvaerts, “The Sound Material of Electronic Music,” in *Die Reihe 1. Electronic Music*, ed. Herbert Eimert and Karlheinz Stockhausen (Bryn Mawr: Theodore Presser, 1958), 37.

later, turned out to “have equal rights, opposite the single frequency.”⁵⁴ Its name is “noise” (*het geruis*): undetermined, unpredictable, chaotic, ever-changing, and endlessly varied sound.

The overconfident attempt to rid music of all external human influences, and thus of the very physicality and corporeality of sound itself, thereby turned out to be a crucial step toward the further emancipation of this “other,” more unruly sound material, defined by what Stockhausen calls “the uniqueness of each event.” In other words, precisely the fundamental inaccessibility and unattainability of sonic purity and the realm of mathematical ideals opened up a road toward a different musical sensibility. This sensibility is not based on idealized transparency but on the sonic exploration of the material agency of media technological processes themselves. Leaving behind the narrow path set out by the complete mathematization and rationalization of sound (which followed the “blueprint for technological advancement”), these electronic contingencies of sound media opened up new musical horizons.

They emphasize that sound media are not just sound *reproducing* machines, but sound *producing* instruments; not transparent or passive channels that can be fully controlled by composers or musicians to transmit unimpeded signals, but active agents of sonic production and manipulation, the intricacies of which escape our absolute control and add complexity, contingency, and singularity to the sounds they (re)produce.⁵⁵ As the distinctive sound of media technology itself turned from unwanted side effect to desired sonic material over the course of the one and a half-century since their invention, and especially since the Second World War, these idiosyncratic effects of the material agency of sound media have become an important part of musical production. They came to shape the sound of music as we hear it all around us in the twenty-first century.

This development might be most apparent in musical genres that use the contingencies of technical mediation as a conscious artistic strategy, by exploiting, as Caleb Kelly writes in this section’s next chapter, “the crack [as] a point of rupture or a place of chance occurrence, where unique events take place.” However, even beyond such approaches that deliberately instrumentalize the limitations of technical mediation by focusing on glitches, breakdowns, noises, failure, and errors, the electronic contingencies inherent to media technological processes profoundly changed the sound of music. Every involvement with technological media forces composers and musicians

⁵⁴ Goeyvaerts, *Selbstlose Musik*, 166.

⁵⁵ On sound media as (musical) instruments, see Jonathan Sterne, “Media or Instruments? Yes,” *OFF|SCREEN* 11, nos. 8–9 (2007). Retrieved from https://offscreen.com/view/sterne_instruments.

to yield some of their authorial control to the unrepresentable processes that occur inside the black boxes that transduce sound into electricity and store it in the form of grooves, magnetized particles, or binary code. Because these processes inevitably leave their mark on the sonic identity of the sounds they (re)produce, these sounds are never closed, stable, predictable, or pure. Instead, they always retain a level of transience, of unpredictable change, of electronic contingency. Ultimately, as Goeyvaerts found out as well, it is precisely *because* and not *despite* of this inherent contingency of media technological processes that they possess the ability to produce the infinitely meaningful sounds of something we continue to call music.

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