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Fourier('s) Analysis: "Sonic" Heat Conduction and Its Cold Calculation[1]

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The techno-mathematical condition of present-day media culture has triggered the discursive interest in temperature-related subjects. We can deal with signal processing either with "hot" imagination-driven theories, which concentrate on its discursive effects, or by a "cold" analysis of its underlying nondiscursive techno-mathematical structures. The "ice-cold" resonates with the media-archaeological research method itself, as a Nietzschean "passion of distance" (Nietzsche, 1886, p. 227).

Temperature is increasingly being referenced in academic discourse.[2] Long before the awareness of climate change and Jacques Derrida's *Archive Fever*, McLuhan (1964) drew a distinction between "hot" and "cool" media depending on the degree of sensual participation on the part of the user. Whereas across the humanities, temperature appears mostly as an image of force, in the nonhumanities temperature figures as a medium. In the technological engineering of communication, it was a decisive step when Shannon (1948) turned entropy—the key term in physical thermodynamics—into a probabilistic measure of the degree of information contained within a message, thereby transforming the physical theory of heat into "cold" mathematical analysis. Another temperature-related term that has gained ultimate importance is the Fourier transform, which is essential to understanding audiovisual signal processing today. Even if this techno-mathematical operation at first glance seems unrelated to "hot" and "cold" media, there is a link. Joseph Fourier started his mathematical operations which since carry his name with heat analysis—such as the flickering air above the Egyptian desert (Siegert, 2003, p. 242)—just like Norbert Wiener's idea to investigate harmonic analysis was inspired by the wave patterns on the Charles River that he observed looking out of his office at the Massachusetts Institute of Technology. What appeared like a *fata morgana* at first sight led to a most efficient computational tool.

In its simplest form, Fourier analysis decomposes complex periodic functions (such as those perceived as "sound") into the sum of simple sine and cosine waves counted in cycles per second (hertz) (Fourier transform, n.d.). Even in its initial conception, Fourier analysis provided a symbolic mechanism to master dynamic physical events by approximation: that is, by converting continuous events into discrete

[1] The following thoughts are part of a research focus on the nature of "sonicity" within technical media: implicit sound as object of knowledge.

[2] One example of this is the interdisciplinary conference "Archives of the Arctic. Ice, Entropy and Memory," which was organized by Susanne Frank and Kjetil A. Jakobsen at Humboldt University, Berlin, September 18–21, 2013.

numbers. By converting a function of time into a new function of frequency, the time domain of a signal is converted into discrete numerical values. As a result, the discrete-time Fourier transform facilitates digital storage and computation of real-world signals and their reperformance, since the operation can be time inverted. High-fidelity reconstruction of time signals is pragmatically essential for audio and video reproduction technologies today. But when the Fourier transform is understood in its epistemological dimension as well, it also inspires insights into the nonhuman nature of technological tempor(e)alities, which is of particular interest to the media archaeological sense of time (Goddard, 2014). Technological media time becomes progressively autonomous from the familiar cultural history. "Media cross one another in time, which is no longer history" (Kittler, 1999, p. 115). The Möbius strip–like entanglement between time and frequency, between analogue vibrations and discrete numbers, is the essence of a time mechanism that is both physical and symbolic at the same time (Miyazaki, 2012)From his research into the relations between heat conduction and abstract numbers, Fourier (1822) derived a general conclusion: "From several mechanical questions arise similar results, such as the isochronism of oscillations, the multiple resonances of sonorous bodies" [Plusieurs questions de mécanique présentent des résultats analogues, tels que l'isochronisme des oscillations, la rèsonnance multiple des corps sonores] (p. 15). His mathematical insight (which had been preconditioned by Leibniz's infinitesimal calculus) is implicitly sonic. Vibrating heat waves are indeed the cause of energy conduction within and between adjacent bodies. Very appropriately, the quanta of thermic wave energy within crystals are called *phonons*. "Second sound is a quantum mechanical phenomenon in which heat transfer occurs by wave-like motion . . . the wave motion of heat is similar to the propagation of sound in air" (Thermal conduction, n.d., para. 1.4).

When it comes to describing microdynamical processes, the language of both physics and electrical engineering frequently refers to terms taken from acoustics, since sonic articulations provide the chrono-poetical model to reflect microtempor(e)alities. Etymologically, Latin *temperare* is related to measured time (*tempus* as cut, as intersection) expressed by harmonic number ratios. The relation between the thermodynamic impulse of Fourier's analysis and "temperature" in music exists in the mathematization of vibrational events: the reversal of time into calculable frequencies like the "well-tempered" tuning of keyboard instruments as it has been developed in Johann Sebastian Bach's composition *Das wohltemperierte Klavier*. This may even result in a retuning of the sounds of the past: "Equal temperament is now universally accepted, but . . . historic temperaments are essential to unlock the emotional charge of earlier music" (Hafner, 2000, para. 1).

Whereas the acoustic signal "heats up" human aural perception, its mathematical analysis cools it down. The discursive fascination with the temperature metaphors of the "frozen" nowadays corresponds with the media archaeological: that is, techno-mathematical approaches such as the synthesis of the human voice that takes place as a coupling of materially refined electronics (*techné*) and mathematical analysis (*lógos*). Boris Yankovsky's Syntonfilm Laboratory in Moscow in the 1930s based its experiments with synthetic sound on mathematical analysis of the genuinely time-critical nature of sonic waveforms as temporal transitions, different from more traditional experiments based on previous sound recordings. Yankovsky's completely formal approach was suspended from any semantically "hot" imagination; artificial voices—resulting from techno-aesthetic "cool" analysis—were not meant to sound specifically human at all: "The final waveform would sound like a 'frozen' vowel" (Smirnov, 2013, p. 215). The techno-mathematical (analytic) approach to speech synthesis results in "cold" voices (Zakharine & Meise, 2013).

While the Greek vocal alphabet had been invented for the special purpose of recording the musicality of poetry (cultural recording as symbolical operation), the current digital code returns to first expressions of pre-Grecian writing that had been invented for *calculating* purposes (Schmandt-Besserat, 1992).

The Fourier transform brings a recorded voice event into the mathematical realm. In digital computing, fast Fourier transformation is the time-efficient algorithmic implementation of this operation, allowing for a kind of real-time speech analysis that only computing can achieve. At that moment, the machine is a better media archaeologist of sound than any human ear. Only by application of such technological tools can the microtemporal level of such events be explained. Therefore the cover of a book on the origins of the vocal alphabet (Figure 1) shows both an image of an early Greek inscription *and* the spectrogram of the same hexametric verse line spoken by Barry Powell, one of the most original scholars on that subject(Ernst & Kittler, 2006); see Powell (1991, 2002). What is meant to be revealed by this juxtaposition is the recursion of the alphabetic writing within spectrographic (alphanumeric) computation: Both techniques were invented for the analysis of the musicality of human speech.

Fourier's decomposition of temperature into harmonic sine waves reaffirms the occidental epistemology of a world ordered by Pythagorean numbers, but results in an overemphasized separation of sound from noise. Nonperiodic functions in fact cannot be derived from Fourier series; the real challenge, therefore, is thermal noise and thermodynamic stochastics. Culture turns from phonocentrism to mathematics—the cool jazz of media theory.

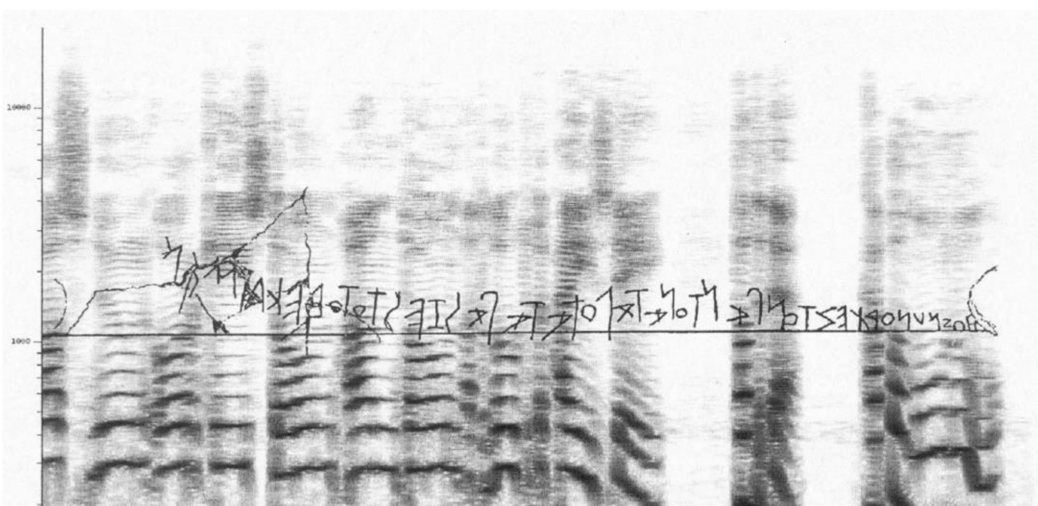

Figure 1. Cover of Die Geburt des Vokalalphabets aus dem Geist der Poesie. Schrift-Ton-Zahl im Medienverbund **[The birth of the vocalized alphabet from the spirit of poetry: Script-sound-number in their medial system].**

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