Miraculous Agitations: On the Uses of Chaotic, Non-Linear and Emergent Behavior in Acoustic Vibrating Physical Systems

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ABSTRACT

"Miraculous agitation" denotes an acoustic *marvel:* a striking sound emerging from vibrating physical systems. A somewhat subjective phenomenon, acoustic marvels are typified by expressive or harmonic richness, and their production is reliant on delicate interrelationships between objects under vibration, often involving chaotic or nonlinear behavior. In some cases it is even possible to observe emergent behavior. Significantly, acoustic marvels may commonly strike the auditor as seeming to be "of electronic origin," thus pointing toward postelectronic electroacoustic techniques. This paper takes a qualitative approach to the examination of such acoustic marvels and their possible applications in new music composition.

The Infinite Sonic Monkey Theorem

The "infinite monkey" theorem supposes that a monkey hitting typewriter keys for an infinite length of time would almost surely reproduce known masterpieces such as the complete works of Shakespeare. It may be assumed that the monkey would also produce outstanding new literature previously undreamt of. A "finite monkey" model of this theorem was tested in 2002 by researchers at Plymouth University, Devon. The project saw six monkeys housed with a word processor for a month. Despite reports of the interface being treated as a toilet by the primates, five pages of text were produced and published in book form as *Notes towards the Complete Works of Shakespeare* [1]. From a semantic point of view, there are "interesting moments" within the monkeys' nonsensical string of letters. Towards the end, the word "mass" can be discerned within the string.

This theorem may also be applied to sound: Within an infinite period of time, any given number of physical vibrating systems—moving in a finite space—will almost surely reproduce all the works of Bach and countless other novel sonic flourishes and interesting moments besides. Hypothetically this model would involve sympathetic influences, modulations and entrainments between vibrating systems. Likewise, a finite model could also be realized using relatively simple vibrating apparatuses and, from these, acoustically interesting moments may be harvested. This paper will explain the philosophy and workings behind these vibrating apparatuses, along with the significance to experimental music of these "interesting sonic moments."

Glimpses of a Post-Electronic Modus Operandi

The fact that we are today surrounded by varieties of physical vibrating systems means that, every now and then, an apparently familiar noise may be evoked as a simulacrum thanks to chance momentary acoustic relationships. To illustrate this, it is not inconceivable that a frequent train commuter might one day hear a momentary carriage noise precisely like the 1-second synth guitar stab from Snap!'s 1990 pop hit "The Power" (if the reader may excuse this cheesy reference). Perhaps, after over a trillion train journeys, a likeness of the ubiquitous vocal hook itself—"I've got the power"—would materialize (on a miraculous day). Obviously, however, the power of these interacting vibrating systems lies not in their potential to eventually produce mundane familiar sounds but in the higher likelihood of thrillingly new, unfamiliar sounds being produced. Occasionally, interesting sonic moments leap from oddments of acoustic furniture to pierce our consciousness [2]. These arresting noises are not merely simulacra of symbolic emotive sounds but strikingly complex modulations suggestive of electronic synthesis, lying between familiarity and nonsense. Such instances point toward a postelectronic modus operandi in the composition of experimental music: techniques borrowed from

Fig. 1. A Zimbabwean *mbira* with two loosely affixed flattened bottle-tops pinned to the soundboard. (Photo © Daniel Wilson)

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electronic music, involving emphases on waveshaping, envelopes and modulations, being applied to acoustic systems. I call these sounds *miraculous agitations*, but a more apt term for the idealized state of miraculousness would be *sonic emergence* [3,4].

CRAFTING SOUND ENGINES

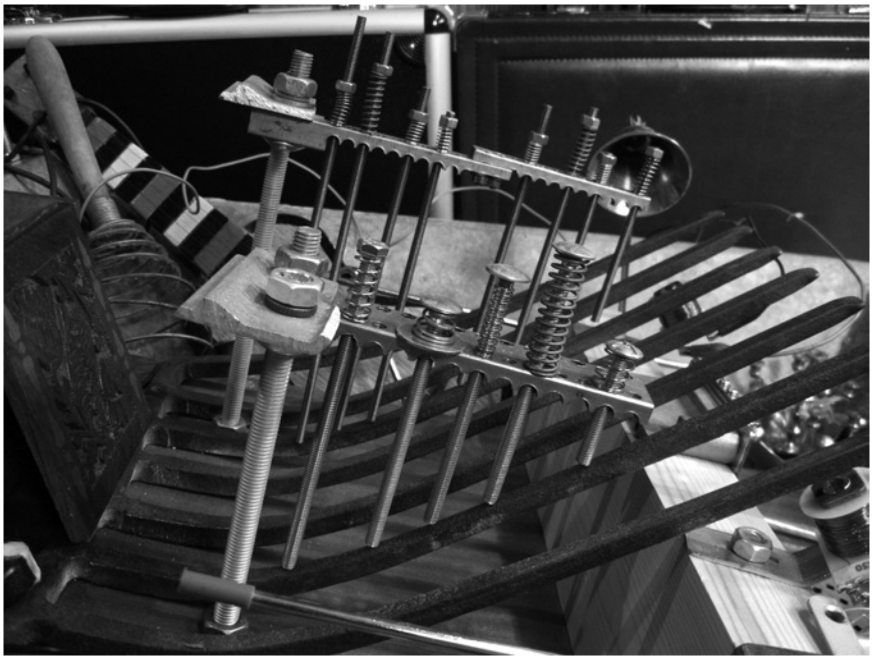
How, then, may one go about building acoustic systems to bring about these miraculous agitations? The construction is not particularly technical, although the resulting effects can be highly complex. A simple demonstration showing how a simple oscillation can be acoustically transformed may be performed by filling a box with assorted household objects, subjecting this box to a vibration between 1 and 1,000Hz, approximately, and observing how the contents of the box interact, create sub-harmonics (and failed sub-harmonics—non-periodic events), chatter and generally vivify the original drive frequency with additional components.

One notable instrument that utilizes chatter to great effect is the *mbira* (also known variously as the "thumb piano" and the "kalimba"—see Fig. 1). Played by flicking metallic keys affixed to a soundboard, the mbira possesses a remarkable feature in the form of "buzzers" often loosely mounted to the soundboard. Multiple bottletops are frequently used as buzzers. Buzzer chatter distorts the tones of the plucked keys in a complex manner (accentuating phasing and adding sub-harmonics) and can give musical information back to the player, echoing phrases, suggesting other melodies or adding new harmonies [5]. Instead of the usual one-way system of creative energies traveling from the player to the instrument, in this case the instrument gives back new information from which the player can learn. Similarly, the miraculous agitation apparatus must be constructed to facilitate such stimulating auditory artifacts. This inspirational potency of our "sound engine" apparatus should be its raison d'être. What is required is a primordial soup—a cauldron of multiple vibrating objects—along with a means of "stirring," manipulating and adjusting the constituent parts and their relationships. The manipulations can be effected through adjustable mechanical parts—gears, jacks, pulleys, plungers, springs, etc.—their mounting arrangements varying according to the designer's whims and the idiosyncrasies of the apparatus. Figure 2 shows a specially crafted umbrella in which adjustable "fingers" elicit varied sub-harmonics by grazing electromagnetically resonated pitchfork prongs.

There are many ways to induce vibration in objects or assemblies [6], but there are three especially effective methods for seeking miraculous agitations:

1. External tone insonification
2. Self-feedbacking elements (electromagnetically resonated parts in a state of feedback)
3. Both of the above together.

Fig. 2. Detail showing two sets of sub-harmonic grazers arching over a vibrating pitchfork head embedded within other vibrating systems. (Photo © Daniel Wilson)



The simplest of the above methods is tone insonification: An agitating signal (such as a pitched oscillator tone) is fed into the apparatus. The actual means of inducing vibration involves affixing piezoelectric agitators or coiled components. My preferred technique is the non-contact electromagnetic field method, which employs a low-resistance fixed-magnet-core relay coil (which may be used with a normal amplifier in lieu of a loudspeaker). Admittedly, however, maintaining a fixed distance from the ferric target can be awkward (a mount or jack must be built). An apparatus may feature multiple means of agitation: adapted loudspeakers, motors, solenoids, etc.

The second method involves allowing parts of the apparatus to feed back upon themselves. This means introducing pickups into the apparatus (if a coil pickup is fed into an agitator relay coil, an electromagnetically sustained resonance is produced, much as in the popular eBow). Multiple systems of feedback allow for entrainment and emergent behavior. Phase and magnetic polarity become critical in such situations. The aforementioned cauldron of stirred, vibrating objects is no mere metaphor. My own experiments have seen random objects each fitted with combinations of pickup and agitator (be it piezo sounder, loudspeaker or any coiled agitator component) along with a small battery-powered amplifier circuit allowing the object to feed back—to resonate—at its own natural resonant frequencies. When many of these "singing objects" are placed into a container, interactions and entrainments are set in motion as each object's own feedback notes vie for precedence. Non-resonated obstructor objects may also be added to the mixture.

The third method gives the best of both worlds, allowing the behavior of the feedback strands to be steered by the external injection of sounds, such as by a variable oscillator.

MANEUVERINGS UPON THE APPARATUS

It should be clear from the above that looseness is vital in such an apparatus. Objects may graze together or move elsewhere, and player control is achieved by physical manipulation on all axes. Any attempt at enclosure—to finalize the apparatus into a definable appliance—

is doomed, as any enclosure would invariably impart its own resonance onto the entire system and limit the possible range of sounds. Instantaneous modifiability is what lends controllability to the apparatus. Figure 3 shows an apparatus in action.

In contrast to the world of electronic music, here it is the cheapest throwaway objects that offer the widest range of application**.** The flimsy nature of cardboard and plastic packaging lends it controllability; for instance, squeezing discards such as plastic cartons will alter their resonant properties. Variable resonance can be harnessed further via the addition of string tourniquets around any flexible carton enclosure, with a tightening "Spanish windlass" rotary control on the tourniquet, clipped to fix the setting. The strangulation of the carton will raise its resonant frequency. Clamps on cartons have similar effects. Depending on how these strangled filter objects are coupled to the source of vibration and how they are recorded, they will have an effect akin to a filter bank when many are used together. Also, the simple layering of paper or card upon a vibrating surface dramatically enriches the overtones.

Fig. 3. Manipulating the sound engine apparatus. (Photo © Daniel Wilson)

Timbre can be transformed when the vibration of a single object is met with physical interference. The apparent tone becomes harsher (more harmonically rich) depending on the inelasticity of the obstructor; a metal interference introduces a click into the cycle of oscillation; a pine wood or hard rubber interference has a mellower, clipping effect on the oscillation; softer materials, however, will have a more subtle effect on the shape of the oscillation before the dampening simply decreases the amplitude, as with the softest obstructors, such as felt. If a resonant object such as a bell is used as an obstructor, it will lend its own voice to the proceedings. The degree of movability of an obstructor is an important factor; a fixed interference will steadfastly truncate the extremes of the oscillation, but if the obstructor is moveable it will undergo momentary displacement (bouncing) between periodic cycles, creating growling sub-harmonics.

Slight alterations to amplifier volume controls linked to their respective agitators can have a huge effect (especially in feedback situations) if systems are predisposed to multiple modes of vibration (harmonic or inharmonic). The best way to explain the effect of amplitude in vibrations between objects is to consider the effect of the bridge on the Indian *tanpura* [7,8]. The tanpura is an extremely sophisticated instrument, consisting of four long thin strings (with rich harmonic content) on a resonant body: Two strings are tuned an octave apart, and the other two are tuned to the same note a fifth above the low octave. These two unison middle strings produce enlivening phasing effects in themselves, but the tanpura's animated procession of overtones is created by the extremely sheer, slightly curved solid bridge. Between the bridge and the strings is placed a small piece of thread where the collision density can be carefully adjusted. When the tanpura strings are plucked downward, the string makes tiny periodic grazing collisions with parts of the bridge that drift as the amplitude of the note decreases. These collisions at different points modify the vibration of the string and coax into existence overtones that were originally absent. The vibration of the fundamental is thereby transformed and recycled into various overtones in tandem with the natural decay of amplitude, yielding a luscious sweep of harmonics.

In the apparatuses, acoustic textures may shift dramatically with only a few microns of movement. Delicacy can be exploited, as shown in Fig. 4: Infrasonic metal tongs (front center) resonating at approximately 10Hz are seen clamped atop apparatus parts to impart modulating wobble at this frequency. With such global volatility, control becomes an engineering conundrum. Most of the time, the player will be *timbre-seeking*, which involves controlling tiny grazings between objects: between touching and not touching. This requires the use of separate enlargement gears—vernier-style reduction drive mechanisms (such as epicyclic gearing systems) giving very high reduction ratios; for instance, a fixable mechanical rotary control may be rotated, say, 90°, which would ideally translate to a 5° movement, thereby providing an expanded control of "collision density" between vibrating objects ("collision density" operates in the interstice between fully coupled and non-coupled). But such a gear would itself be subject to vibration through its coupling to the apparatus, inevitably leading to acoustical/dynamical complications. If it were not for judicious listening and vibratory haptic feedback, the instrumentation would be more or less unplayable. To further complicate matters, the player will also be exploring the apparatus with microphones to capture the actual emergent moments, or miraculous agitations.

In effect, the apparatus is a mechanical "acoustic synthesizer" or sound engine: a device anyone can build, regardless of any previous engineering or electronics experience, and any single person's acoustic apparatus will be unique—shaped by environmental circumstances and bearing the fingerprint of its creator. At a 2009 Miraculous Agitation Workshop in Munich, participants salvaged a vast amount of scrap from a nearby yard to

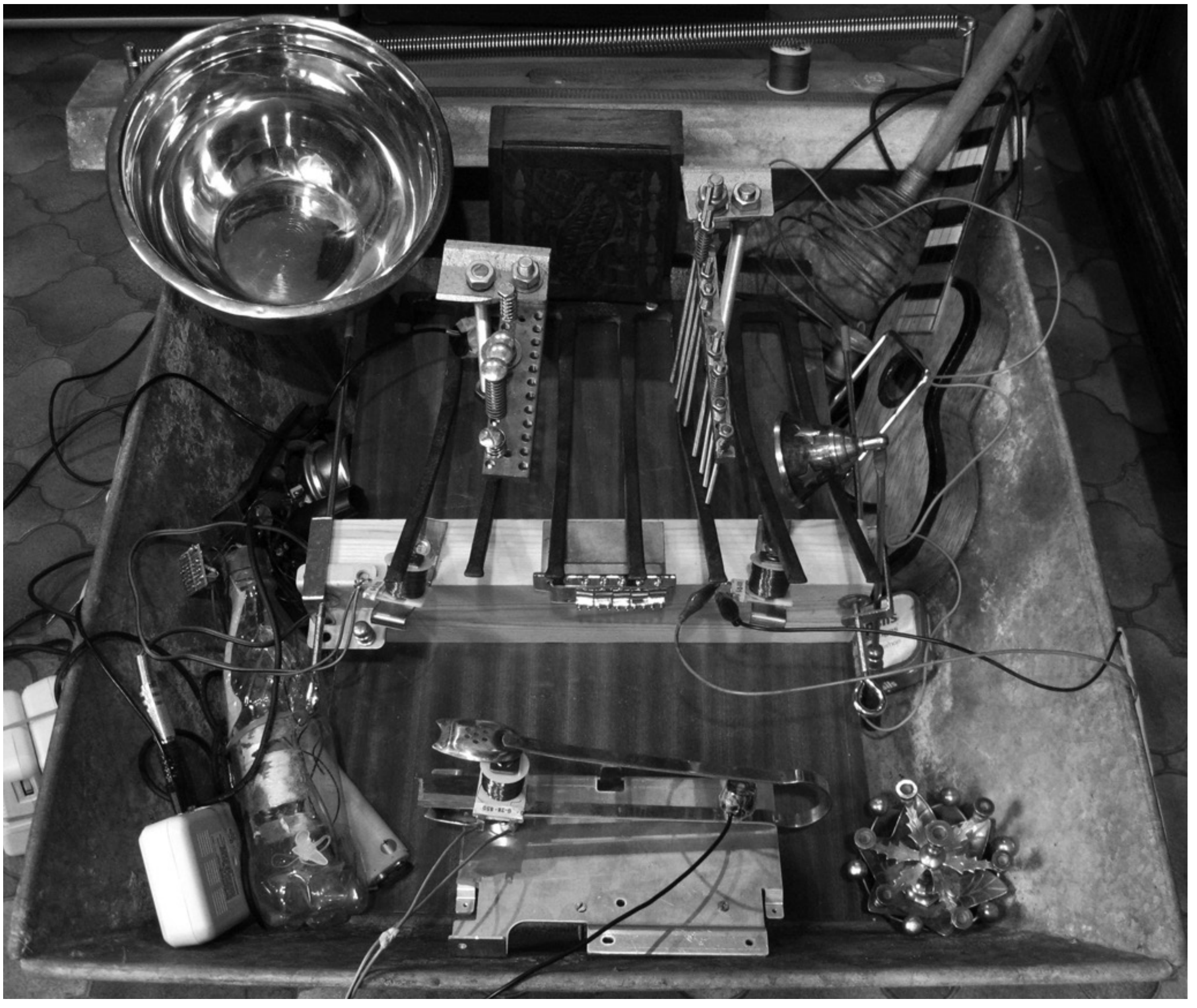


Fig. 4. Sound engine apparatus held in a wheelbarrow body. (Photo © Daniel Wilson)

use for their sound engine apparatuses. Here, one artist confided to me how he noticed that each person's apparatus seemed to uniquely reflect that person's personality. The freedom of choice in the material construction brings about this often-unintended personalization.

How participants tackle engineering conundrums may also reveal characterful solutions. One possible unifying feature is a wheeled base, so that when the workshop participants have finalized their apparatuses, a final performance may see all apparatuses acoustically coupled together, creating one single massive sound engine, thereby increasing the chances of complex and emergent acoustic behavior. Yet even if no definite miraculous agitations emerge, a multitude of live systems is a potent orchestra. The communal interaction of sound engines can thus revolutionize the traditionally insular production of experimental music.

Scrounging through the System

It is well known that physical vibrating systems, bounded by motion obstructors or other vibrating systems, will exhibit chaotic and non-linear behavior [9,10]. The general unpredictability is compounded by mechanical hysteresis (especially if powerful amplifiers driving solenoid-style tappers are in use), which can gradually alter the acoustic qualities of the parts. The chances are that if a particular sonic effect is heard, it is unlikely to be exactly reproduced again. To capture these fleeting flourishes, one must disport oneself in a caper of microphonic inquiry. Figure 5 is a photograph from a workshop showing a peculiar effect being acoustically pinpointed on the apparatus. The infinite world of the real provides endless creative opportunities, but one must scrounge through the system to find colorful and useful sonic material.

Holding any preconceived ideals of the kind of wondrous sound one wishes to create is an unnecessary burden in miraculous agitation generation. Playing an apparatus becomes a drawn-out process of scrounging. Scrounging is not only the principal playing technique but also a valuable means to obtain actual parts for the apparatus.

Accumulating a collection of physical sound objects is a slow and arduous process far removed from the instantaneity offered by modern computer technology. During scavenging, objects offer themselves up unexpectedly: maybe an old dented tool rack is sighted in a dumpster—a discovery that may yield unpremeditated effects when subjected to certain forces. In his book *Empire of Scrounge*, Jeff Ferrell notes that to scrounge is to embrace a Zen of scrounging: a sense of not wanting what one does not have, along with humility and patience in waiting for possibilities to emerge outside one's own control [11]. Effective apparatus components cannot simply be newly purchased, as age and antiquity inevitably contribute to making objects noisier. For instance, a squeaky rotary mechanism is difficult to make from brand-new materials, although leaving it outdoors for a few months and immersing it in hydrochloric acid may help. Certain dents and corrosions create subtle rattling and harmonic qualities. Arranging vibrationally fortuitous object-combinations is a process similar to alchemy. Likewise, when playing the sound engine apparatus, one must continue scrounging—scrounging the system for miraculous agitations by continually permuting the countless variables.

Although the philosophy behind the "sound engine" borrows modes of thought from classical electronic sound synthesis, the method of playing is quite dissimilar. Electronic technology may offer flexibility and provide expedient solutions, but if time- and labor-saving devices are applied in explicitly creative tasks, the act of creation itself (which demands experimentation, meditation and some kind of mental or physical expenditure) is compromised, and its fruits will lack depth of conceptive resolution and dimensionality. When creation is a gradual process, it allows changes to be made at any moment to alter the course of development; this creates a field of interruptive extrusions into diverse dimensions, in effect enhancing the work's conceptive resolution—its *interestingness*. Time must be drawn out, not compressed, if we are to scrounge for miraculous agitations. As Ferrell remarks on the art of street scavenging, it is beneficial for the scrounger to proceed at a slow pace to notice and investigate things [12].

When a collection of recorded miraculous agitations has finally been amassed, it is up to the composer/player to decide how to implement them. They may be edited together to form a "study" or used as indicators to follow up certain effects in the construction of instruments or components for ever-more-sophisticated apparatuses.

Conclusion? (Or the Beginning?)

The use of these apparatuses in electroacoustic and experimental music may go some way to help capture the inquisitive ear of the listener [13]. There is an intractable Gordian knot at the center of contemporary electroacoustic music, as the composer is beset by obligations to obscure or conceal methods to avoid recognition by the listener of the processes used. This is brought about through the common usage of mass-produced technologies involved in composition and pushes the composer into a near-paranoid state. The composer becomes inclined to preserve the uniqueness of a composition or performance through secrecy. Such steps are necessary to avoid the peril of what composer Denis Smalley identifies as "technological listening" [14], wherein the listener is able to perceive the technological processes and manipulations present within the music, to the detriment of the musical expression itself (much as in stage magic, where an audience member perceiving how a magic trick works destroys the entertainment). The end result is a tendency toward thaumaturgy in today's electroacoustic music—"miracle-working" for self-interest and prestige [15].

The electroacoustic composer's inner thaumaturge can be subjugated through the implementation of unique, composer-built physical apparatuses—sound engines—whereupon the creative process is centered. Such sound engines have the potential to democratize the production of electroacoustic music, divesting it of all hardware/software brand fetishism and fostering a more engaging mode of listening. Electro-mechanical means to generate, mutate and process tone may seem a cumbersome retrograde step but it is in fact a logical progression. Equipped with concepts acquired from the analogue/digital electronic domain, the electroacoustic composer can find physical analogues of those electronic "virtual" treatments, and much more, in the real world [16].

With miraculous agitation apparatuses, the composer is relegated to listener, in the thrall of these miniscule acoustic perturbations. The composer's task becomes one of making a coherent whole from the interesting moments gifted by chance through perseverance. The listener (now on a par with the composer) may then actively dissect the acousmata by ear to ascertain the nature of the apparatus, its construction and its effects, compelled to listen on through awareness of its acoustic origins and the curiousness of its shape or mechanisms [17].

As the "modules"—the elements of the apparatus—may be found anywhere and recycled, the exclusivity that often accompanies technology-based experimental music is dispensed with. The gruntwork involved in engineering the apparatus may give the misleading illusion that this is a somewhat masculine pursuit, but conversely the actual maneuverings require supreme delicacy and gentle caress. The miraculous agitation apparatus redefines experimental music as a folk art, accessible to everyone. Truly, if enough patient people adopt these apparatuses and work with them like the "finite monkeys," outstanding and seemingly miraculous new music will peek out from the vibratory broth.

Fig. 5. Searching for the source of a complex sound during timbre-seeking practice at a Miraculous Agitation workshop, Munich, 2009. (Photo © Michael Kurz)

References and Notes

1. Elmo, Gum, Heather, Holly, Mistletoe and Rowan (Sulawesi crested macaques from Paignton Zoo Environmental Park), *Notes towards the Complete Works of Shakespeare* (London: Kahve-Society, 2002).

2. D. Wilson, "An Annotated Bibliography of Vibrational Enigmas," unpublished typescript, [no date]. The appendix of this as-yet-unpublished typescript contains collected anecdotes from different correspondents listing instances of heard acoustic marvels. This ever-expanding collection of quotes contains such descriptions as that of the chatter of grazing bottles modulated by the hum of a refrigerator's mains, a torsional vibration induced mid-swing in a squeaky-hinged door, the creaks and buzzes of an old rowboat on unsettled waters, etc.

3. D. Wilson, "Albatross; Or, on Miraculous Agitations," in *Dropping Out* (Hertfordshire, U.K.: self-published, 2006). The title *Albatross* refers to the burdensome nature of the apparatuses: weighty, difficult to transport and awkward to control.

4. For an introduction to emergence, see S. Johnson, *Emergence* (London: Allen Lane, 2001); M. Bunge, *Emergence and Convergence* (Toronto: Univ. of Toronto Press, 2003).

5. P.F. Berliner, *The Soul of Mbira: Music and Traditions of the Shona People of Zimbabwe* (Chicago, IL: Univ. of Chicago Press, 1993).

6. There are many alternative ways to induce vibrations non-electrically. A cello bow may be used if the apparatus permits. Air pumped through adjustable, nodally waveguided rubber tubes may be cumbersome: J.E. Malcolm, "Oscillatory Flow in an Air-Filled Elastic System," in *Nature* **192**, No. 4805 (1961) p. 875. Another method involves singing a pitched tone into a tube attached to the assembly (the "eidophone" method): M.W. Hughes, *Voice Figures* (London: Hazell & Watson, 1891); M.W. Hughes, *The Eidophone Voice Figures* (London: Christian Herald, 1904). Other, more transitory resonating methods successfully used for powder-based sound visualization include Joseph Goold's technique, employing tuned elastic rods to rub anti-nodal points into resonance: J. Goold et al., *Harmonic Vibrations and Vibration Figures* (London: Newton & Co., 1909); and Mary Waller's dry ice on metal: M.D. Waller, *Chladni Figures* (London: G. Bell & Sons, 1961). My own experiments have revealed another method, wherein air is blown through a pipe terminating with an open-lipped "mouth" upon which is placed a thin, weighted flat surface horizontally covering the mouth. This pipe may be adapted to split off into multiple mouths to agitate different objects simultaneously.

7. H.V. Modak and K.V. Desa, "Study of Vibration of a String over a Tanpura Bridge," *Journal of the Acoustical Society of India* **13**, No. 3, 121–123 (1985).

8. C.V. Raman, "On Some Indian Stringed Instruments," *The Proceedings of the Indian Association for the Cultivation of Science* **7** (1921) pp. 29–33.

9. S.R. Bishop, "Impact Oscillators," *Philosophical Transactions: Physical Sciences and Engineering* **347**, No. 1683 (London: The Royal Society, 1994) pp. 347–351.

10. F.C. Moon, *Chaotic and Fractal Dynamics: An Introduction for Applied Scientists and Engineers* (Weinheim, Germany: Wiley-VCH, 2008).

11. J. Ferrell, *Empire of Scrounge* (New York: New York Univ. Press, 2006).

12. Ferrell [11].

13. Some case studies composing an overview of sonic art's social aspects may be found in D. Wilson, "Sonics in the Wildernesses," *The Brooklyn Rail* (April 2011) pp. 68–69.

14. D. Smalley, "Spectromorphology: Explaining Sound-Shapes," in *Organised Sound* **2**, No. 2, 107–126 (1997).

15. Personal correspondence with Christopher J. Weaver (station manager of London's Resonance 104.4FM) disclosed numerous first-hand accounts of experimental radio artists concealing their methods. One of the most illuminating: Weaver notes how his casual inquiry to sound artist Christina Kubisch, regarding her impressive induction method (for wirelessly conveying sound to headphones without interference), prompted her reply: "I have developed my personal induction system at the end of the 70s, it is now protected (patented) and I use it as part of my personal artistic language." Kubisch's reply is understandable and serves to illustrate the point.

16. However, the digital realm need not be neglected. At a miraculous agitation workshop, one participant suggested crafting custom software to allow a computer to continuously analyze incoming recorded sound to detect the "interesting moments" for later isolation.

17. Electroacoustic music and sonic art are rather internally conflicted practices, being part art, part science. Art is noted to cling to esoteric heroic notions of inspiration, while science (or at least, Baconian science) dismisses such notions, espousing the view that discovery must be a collective cooperative endeavor of continual experimentation. That is not to say that science does not have its adherents of "heroism." For an excellent overview of these conflicted viewpoints, specifically in science, see D. Lamb and S.M. Easton, *Multiple Discovery: The Pattern of Scientific Progress* (Avebury, U.K.: Avebury, 1984).

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