

At the age of 16, I read of the earth-battery experiments of Scottish inventor Alexander Bain, who had generated a permanent voltage by use of buried metal plates that could power the prime mover of an electric clock.<sup>1</sup> Inspired by the idea of permanent free power, I built an earth battery constructed of alternating plates of lead and zinc buried in the topsoil. This created a measurable but small permanent current of slightly under one volt. At the time, I believed this voltage to be entirely the result of chemical-electric effects similar to that achieved by the insertion of electrodes into a lemon or a potato.<sup>2</sup>

Earth batteries were developed in the 1840s and were used to power the communications between telegraph stations. Many patents were granted for variations on the same concept, where plates of two different metals are buried in the soil, which acts as an electrolyte similar to a lead acid battery. Lord Kelvin developed a sea battery and discovered that the resulting voltage was not due to a chemical process as the orientation of the plates would alter the amount of current measured, something that would not occur with the plates of a chemical battery.<sup>3</sup> The discovery of an electrical potential between the stations of the telegraph, along with the voltage differentials demonstrated by the sea battery, suggested the existence of naturally occurring electrical currents flowing in the earth. These were named telluric currents after the Latin *tellus*: the earth.<sup>4</sup>

The fundamental causes of telluric currents have been understood since the late twentieth century. In their study of the interactions between telluric currents and man-made electrical systems, Lois Lanzerotti and Giovanni Gregori explain that telluric currents

are produced either through electromagnetic induction by the time-varying, external-origin geomagnetic field, or, whenever a conducting body (such as seawater) moves (because of tides or other reason) across the Earth's permanent magnetic field.<sup>5</sup>

They are also fed by and have a direct relation to lightning from thunderstorms.<sup>6</sup> Telluric currents encircle the globe and are used by geologists and geophysicists to determine the nature of underlying rock formations. Geophysicists have published charts illustrating their global distribution.<sup>7</sup> The currents are of extremely low frequency and voltage and have collective regular periodic fluctuations; they are diurnal and tend to follow the direction of the sun. Perturbations in telluric currents occur simultaneously over the entire globe as measured by global networks of instruments.

## SONIFICATION

Sonification is the interpretation of information through sound. One of the first sonifications was the Geiger counter, which creates sound in response to the presence and intensity of radiation. Sonification can be a direct and immediate conduit to an intuitive understanding of the nature of the phenomenon under observation. My interest lies in the direct sonification of the signals themselves, or at least in employing a process that uses as little mediation as possible. Preferably I'd like to develop a technique that preserves naturally occurring informational patterns so that the observer can perceive the nature of the phenomena directly and in real time. The aesthetics of such raw sounds (often understood as visualisations rather than sonifications) can be relatively unfamiliar and inaccessible, but they do represent actual phenomena. The sounds we hear are shaped by external information and are a faithful portrayal of the unseen. Through sonification a window is opened to an understanding of something that otherwise would remain hidden.

Paul Vickers divides sonification into two forms that show how data can be mapped to sound:

... direct mappings impose a one to one relationship between data items and sonic events (possibly involving some scaling and quantisation) whilst metaphoric or analogic mappings impose interpretive filters or mapping functions to the data before it is rendered.<sup>8</sup>

Vickers notionalises this relationship as a continuum between what he terms 'Ars Informatica' and 'Ars Electronica.' At the Ars Informatica end of the continuum sonification is a direct mapping of the data with little or no artistic intent, while at the Ars Electronica end sonification exists as pure art form with little or no attempt to communicate ideas from the real world.<sup>9</sup> It is possible however that artworks can directly sonify data and inhabit a space in between Ars Informatica and Ars Electronica. The following artworks can be considered as works that occupy both ends of this continuum simultaneously.

Christina Kubisch's *Electrical Walks* (2003) involve the participant wearing specially designed magnetic headphones with built-in coils that respond to electrical fields and produce sound in the wearer's ears.<sup>10</sup> The artist supplies participants with headphones and a map showing the locations of the fields to visit. In a short journey, the participant can listen to the otherwise unseen fields of light systems, transformers, anti-theft security devices, surveillance cameras, cell phones, computers, elevators, streetcar cables, antennae, navigation systems, automated teller machines, neon advertising, and electric devices. Kubisch says,

The perception of everyday reality changes when one listens to the electrical fields; what is accustomed appears in a different context. Nothing looks the way it sounds. And nothing sounds the way it looks.<sup>11</sup>

Kubisch makes a point of not labelling this ecology as good or bad:

I could tell everyone that I think it's bad. But that wouldn't be an experience. It would just be didactic. On the other hand, this stuff is very fascinating as well.<sup>12</sup>

Kubisch's work reveals the unseen aspects of a local environment and transforms what might be regarded as electromagnetic pollution into a source of illuminating information. It is a direct-mapping sonification revealing an electromagnetic ecology emanating from our technology, and yet the work is clearly art; both Ars Informatica and Ars Electronica.

Australian cross-disciplinary artist Joyce Hinterding's gallery work, *Aeriology* (1995), is an extensive antenna array directly sonifying local airborne VLF phenomena.

Made from over twenty kilometres of copper wire that has been wrapped around the gallery's architecture, *Aeriology* transforms the space into a beautiful walk-in radio antenna. Through sympathetic amplification the harmonising coils of this installation reveal otherwise unheard activity turning the ethereal into audio.<sup>13</sup>

Hinterding describes *Aeriology* as a machine for a *techné* of the invisible.<sup>14</sup> The work reveals the unseen signals of the air, both man-made and naturally occurring. Hinterding also found that electromagnetic pollution from the city's electrical distribution system pervaded the local electromagnetic ecology:

... if you listen to the VLF antenna in the middle of a city, you really cannot hear much except for a big 50 hertz hum. ... So the strongest element in the local city electromagnetic landscape at the VLF end of the spectrum is the sound radiating off our electrical system. But if you go somewhere away from electrical powerlines you will hear a whole range of other sounds.<sup>15</sup>

*Aeriology* reveals another unseen electromagnetic ecology using simple technology to achieve a directly mapped sonification that exists as both art and science.

Other cross-disciplinary artworks drawing on science as a source for sonification have explored naturally occurring signals. Artists have used the phenomena of space, such as Radioqualia's *Radio Astronomy* (2004); of protein data in John Dunn and Mary Anne Clark's *Life Music* (1998); and of seismic data, as in Marty Quinn's *Seismic Sonata* (2001).<sup>16</sup> It is true that the human sensory apparatus of perception struggles to directly perceive many phenomena. Illustrating the unseeable invariably involves format- or state-shifting, shifting the temporal scale, or otherwise reinterpreting the data. If the artistic intent of the work is to illustrate the unseen, as little mediation as possible will most effectively meet that goal. In an attempt to meet this challenge, my work *Mains Hum* (2009) drew on the signals of the ground for its directly mapped sonification.



Figure 1. Pete Gorman, First Sonification of Pervasive Electro-Pollution (2009).

## STRAY VOLTAGE

Almost 30 years after my earth battery experiment, I thought to revisit the idea. I went out into the backyard and inserted two copper rods into the ground. When I measured these with a voltmeter I was amazed to discover about 0.3 volts just pouring out of the ground. This could not be a chemical battery effect as both electrodes were of the same metal. I moved these makeshift electrodes around a variety of places in the backyard and found the voltage was present at about the same strength everywhere. I connected the electrodes to a pre-amplifier, in turn connected to an amplified loudspeaker in order to hear this ubiquitous signal. The resulting sound was a rich textured hum comprising a 50 Hz bass tone with layers of harmonics at intervals based on that frequency. The hum was not fully constant; various artefacts could be heard; there were sudden alterations in the frequency distribution, clicks and spurious noises. Inspired, I hauled out a 300 watt PA system with mains cable and really gave it voice. This constituted the first iteration of my *Mains Hum* installation, although the neighbours probably didn't recognise it as such.



Figure 2. Pete Gorman, First *Mains Hum* installation (2009). Port Chalmers, Dunedin.

I realised that the signal I was finding in my backyard must have been coming from the electrical mains as it was a familiar frequency, being of the same pitch as a short circuit or unearthed audio signal. Furthermore, the sound could be altered by turning the oven on and off despite the ground electrodes being more than ten meters away.

I then took the pre-amplifier, electrode apparatus and my laptop out into the field to see if I could find and record this signal in other locations. The further away from town (and my own backyard) I got, the more the mains hum signal level dropped away. I needed a much more advanced instrument to be able to hear it than my simple handmade pre-amplifier, which only amplified the signal by 40-50 times. I could hear the same signal faintly about 5 kilometres from my backyard on a nearby mountain, about 7 kilometres away in the forest and, just barely, 12 kilometres away on the beach. Distance from the city had a clear impact on the signal strength.

So where does all this electricity come from, and, as it pervades a large amount of human and animal habitat, how does it affect the organisms living in or on the ground? The man-made electrical current that produces this mains hum is very pervasive; it predominates over the more subtle naturally occurring telluric currents many kilometres from a major town, city, or large-scale electrical installation such as an electric train system, power station or certain type of factory.<sup>17</sup> Mains voltage pollution has been detected emanating from electric trains at distances ranging from a 20km distance in Montreal to as far as 11.5km from the Paris–Toulouse electric railway.<sup>18</sup> Dahlberg suggests that the proliferation of electrical generation and distribution systems is responsible for radically altering the nature of the ground currents flowing in the uppermost layer of the earth.<sup>19</sup>

The neutral wire in the entire system was wired to the earth through the ground rods and other connections in the earth. This connection has produced an electrical distribution system, which uses the earth in parallel with the neutral wire as the return path for the electric current.<sup>20</sup>

To increase safety from electrical shocks, distribution companies increase the number of earthing points, often using water pipes and earthing rods that feed current into the ground. Dahlberg continues:

The present multi grounded system has the disturbing effect of placing every living organism in contact with one terminal (the neutral wire) of the entire electrical distribution system ... As human beings, we literally stand on one terminal of the electrical system with no way of escaping that state. The consequences of this continual contact are numerous. An assumption has been made that the multi grounded system places living organisms on an equipotential plane, the earth connected to the neutral of the system. An additional assumption follows, that an equipotential plane is an electrically safe place to be.<sup>21</sup>

Stray voltage is the extraneous voltage that is generated on grounded surfaces when current flows through the resistance of a ground path.<sup>22</sup> The term is used to refer to small electric shocks coming from inadequate wiring of a localised electrical system.<sup>23</sup> Stray voltage in dairy barns, thought to be from frequent small electric shocks, has long been known to cause problems for livestock.<sup>24</sup> Dahlberg describes these effects “includ[ing] a sudden onset of a number of bacterial diseases as well as a gradual deterioration of the muscle and skeletal structure of the body.”<sup>25</sup> The cows are thought to receive small shocks when contacting the metal of the barn. Dahlberg suggests that constant exposure to electromagnetic ground currents from natural and man-made sources are more likely responsible.

When researching the possible effects on organisms of exposure to these artificial ground currents, I quickly realised that there is little science being done in this field. There are many organisms that use or are affected by the earth’s magnetic fields, however, and electrical currents produce magnetic fields including our telluric ones. Ground currents have been shown to cause induced currents in trees.<sup>26</sup> Magnetic fields are known to be used for navigation by birds, but are also used by ground-dwelling aquatic bacteria.<sup>27</sup> Little is known about the effect of these types of fields in humans, although enhanced DNA synthesis has been reported for human fibroblasts exposed to magnetic field fluctuations with frequencies and amplitudes similar to many geomagnetic occurrences.<sup>28</sup> Liboff points to a possible mutagenic effect:

The range of magnetic field amplitudes tested encompass the geomagnetic field, suggesting the possibility of mutagenic interactions directly arising from short-term changes in the earth’s field.<sup>29</sup>

Another study shows an interaction between magnetic fields and biological systems within similar ranges of magnetic field strength.

Cell studies show that magnetic fields at some frequencies, amplitudes, and wave forms interact with biological systems ... Cellular and physiologic studies thus suggest effects that may be related to cell multiplication and tumor promotion.<sup>30</sup>

What can be seen from the above is that the electricity in the ground is coming from our system of electrical distribution via a large number of grounding points acting as conduits channelling voltage into the ground. The ground acts as part of the electrical circuit. These man-made ground currents greatly dominate an electromagnetic ecology that once would have consisted of not much more than the subtle and varied naturally occurring telluric currents. While this collection of results and responses can hardly be considered scientific proof of immanent danger, it equally cannot be said that these ground currents can be considered entirely benign. It may be appropriate to refer to these artificial ground currents as electromagnetic pollution. It seems that an artistic response to this collection of data is also appropriate. My *Mains Hum* sonification directly maps information about the presence of this electricity and provides an opportunity to apprehend aspects of its nature. The work exists simultaneously as both *Ars Electronica* and *Ars Informatica*.

### *MAINS HUM* (2009)

These findings formed the basis for my recent performative sonification work *Mains Hum* (2009).<sup>31</sup> For this, I constructed a set of large copper electrodes and inserted them into the ground to pick up the electrical signals of the site. I fed the signal into a pre-amplifier circuit and then into an audio mixer and P.A. system. I then let the machine I had assembled give voice to the ground's electromagnetic environment.



Figure 3. Pete Gorman, *Mains Hum* (2009), Dunedin School of Art. Photograph by Ted Whitaker.

What was surprising was the amount of texture and variance of sound in the hum. The sound contained spontaneous artefacts, sudden pulses, clicks and slight pitch and timbre changes. The cause of these perturbations most likely corresponded to changes in the city's electrical demand or the change in electricity use of nearby buildings as various machines or processes were activated or deactivated. It is also possible that some interaction between the man-made electrical currents and the ground's natural electromagnetic ecology may have been responsible for some of these variations. The work served to draw attention to the existence of this electricity in the ground and suggested an awareness of it as electrical pollution. The signal exists as a voltage in the ground and, in order to make it audible, the signal shifted states from an unseen voltage to acoustic sound waves. The sound when amplified to a moderate to loud volume can be challenging for the visitor to the space; it can be perceived as some type of malfunction. Many in the audience of *Mains Hum* assumed that the sound they heard was produced by direct amplification of sound in the earth, as if from a buried microphone. In order to have the work read, it is necessary to make available the requisite information. The sonification itself cannot give the full range of information for interpretation and source simultaneously; listeners need both *Ars Informatica* and *Ars Electronica* in order for the work to make sense. This type of cross-disciplinary sonification, which involves both *Ars Electronica* and *Ars Informatica* together, can be an effective technique, bringing attention to the existence of unseeable electrical processes and raising questions around what human activity may be doing to natural electromagnetic ecologies.

In the early twenty-first century telluric currents have not yet disappeared, but our ability to perceive them is becoming weaker. Overtaken by a different disciplinary formation of electronic pollution, the telluric current deserves to be heard. A future project may be to design and construct another installation apparatus that can eliminate the mains hum pollution to reveal and sonify the naturally occurring telluric currents, revealing another electromagnetic ecology, that of the Earth itself.

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