

Berklee College of Music

# **Static Variable:**

An Electromagnetic Nexus

Submitted in Partial Fulfilment of the Degree of  
Master of Music in Music Production, Technology, and Innovation

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## Table of Contents

Acknowledgements	iv
Abstract	v
1. Introduction	1
2. Review of the State of Art	4
3. Description	10
3.1. Origin	10
3.2. Preliminary Preparation	11
3.3. Prototype #1	13
3.4. Amendment #1	13
3.5. Prototype #2	16
3.6. Amendment #2	16
3.7. Prototype #3	19
3.8. Amendment #3	19
3.8.1. Static Variable	19
3.8.2. Blackscreen	19

4. Innovative Aspects	22
5. New Skills Acquired	23
6. Challenges	24
6.1. Unexpected	24
6.2. Expected	25
7. Future Ramifications	26
7.1. Blackbox	26
7.2. Blackbox Remote	26
7.3. Blackbox VR	27
8. Conclusion	27
Appendix A	28
Appendix B	29
Bibliography	30

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## **Abstract**

This work is the first in a series of projects collectively known as Static Variable. The series will raise awareness about electromagnetic pollution through various online and offline multimedia artworks. These artworks will focus on the sounds of changing electromagnetic fields detected, amplified and recorded by bespoke interfaces. The first multimedia artwork is titled Blackscreen and will feature an ambisonic composition presented as a binaural mix with accompanying audio-reactive visuals. This project will be a commentary on the omnipresent nature of electromagnetic sound ecologies. It will also showcase the limits of human perception by presenting a soundscape which is otherwise imperceivable by humans. This installation will generate awareness regarding the ubiquitous presence of wireless electromagnetic networks and their effects on the ecology.

*Keywords:* Electromagnophony, electromagnetic sound ecologies, sonic art, transmission art, art installation, immersive audio, binaural audio, spatial audio.

## 1.Introduction

Bernie Krause in his TED talk, The Voice of the Natural World, mentions three different sources of sound that can exist in a soundscape and defines them to be sound ecologies.<sup>1</sup> The first of these sound ecologies is geophony, which consists of non-biological natural sounds such as the movement of the earth or the sound of waves, etc. Biophony is the second acoustic source and it is the “collective signature produced at one time by all sound-producing organisms in a given habitat”.<sup>2</sup> The last of these sources is referred to as anthropophony which are the human-generated acoustic signatures. Some of these sources are controlled, such as music or language, while others are incoherent and chaotic, thereby being termed noise. This project focuses on a unique but ordinarily imperceptible subset of anthropophony which the author identifies as electromagnetic sound ecologies or electromagnophonies.

Electromagnophonies comprise of all the waveforms present in the electromagnetic spectrum and it ranges from 3Hz to 300EHZ.<sup>3</sup> Table 1., as indicated in the following page, lists the entire spectrum of electromagnetic waves which are currently identified. This particular project focuses on the capture, documentation and playback of electromagnetic waves within the range of 3Hz to 300GHz. This range corresponds to the frequencies used by radios, cell phones, televisions, global positioning systems, microwaves, communication systems, radar and security systems.<sup>4</sup> The prevalent use of these aforementioned devices and methods of communication in modern society has ensured the omnipresence of electromagnetic waves.

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1. Bernie Krause, “The voice of the natural world”, filmed June 2013, TED Video, 14:37, [https://www.ted.com/talks/bernie\\_krause\\_the\\_voice\\_of\\_the\\_natural\\_world](https://www.ted.com/talks/bernie_krause_the_voice_of_the_natural_world)

2. Krause, “The voice of the natural world”.

3. Richard Sheposh. 2017. “Electromagnetic Spectrum.” Salem Press Encyclopedia of Science. <http://catalog.berklee.edu:2067/login.aspx?direct=true&db=ers&AN=125600158&site=eds-live>.

4. Sheposh, “Electromagnetic Spectrum”.

**Table 1. Electromagnetic Spectrum.**

Class			Frequency
<u>Ionizing radiation</u>	γ	Gamma rays	300 EHz
	HX	Hard X-rays	30 EHz
			3 EHz
	SX	Soft X-rays	300 PHz
			30 PHz
	EUV	Extreme	3 PHz
300 THz			
<u>Visible</u>	NUV	Near	30 THz
			3 THz
	NIR	Near infrared	30 THz
			3 THz
	MIR	Mid infrared	300 GHz
			30 GHz
<u>Microwaves and radio waves</u>	EHF	Extremely high	3 GHz
			30 GHz
	SHF	Super high	3 GHz
			300 MHz
	UHF	Ultra high	30 MHz
			30 MHz
	VHF	Very high	3 MHz
			3 MHz
	HF	High	300 kHz
			30 kHz
	MF	Medium	30 kHz
			3 kHz
LF	Low	3 kHz	
		300 Hz	
VLF	Very low	300 Hz	
		30 Hz	
ULF	Ultra low frequency	30 Hz	
		3 Hz	
SLF	Super low	3 Hz	
		3 Hz	
ELF	Extremely low	3 Hz	
		3 Hz	

Source: Wikipedia, accessed November 13, 2019. [https://en.wikipedia.org/wiki/File:Light\\_spectrum.svg](https://en.wikipedia.org/wiki/File:Light_spectrum.svg)

The ubiquitous nature of these electromagnetic waves have given rise to questions regarding their effect on the physiology and wellbeing of living organisms. Research at the Oceania Radiofrequency Scientific Advisory Association has shown that chronic exposure to RF electromagnetic waves is associated with increased oxidative stress and DNA damage in human beings.<sup>5</sup> A separate study conducted on the effects of electromagnetic radiation from cell towers on the Asiatic honey bee found that the colonies in close proximity to mobile phones towers were most affected by electromagnetic radiation. The flight activity and returning ability of worker honey bees were maximum in colonies placed at 500m and minimum at 100m from the tower.<sup>6</sup> The Caribbean spiny lobster, *Panulirus argus*, is a migratory crustacean that uses Earth's magnetic field as a navigational cue.<sup>7</sup> These species that use magnetoreception for navigation are sensitive and susceptible to anthropogenic electromagnetic fields.

The author's decision to work with electromagnetic sound ecologies is driven by the desire to generate awareness about electromagnetic pollution. In order to facilitate this process it is necessary to bring to light an otherwise invisible, inaudible and completely intangible medium. This is to be achieved by amplifying and recording electromagnetic emissions thereby engaging in the process of creating transmission art.<sup>8</sup> The goal is to utilise transmission art to initiate discourse about electromagnetic pollution by increasing awareness regarding the omnipresent nature of electromagnetic waves and their effect on other living beings.

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5. Priyanka Bandara, Steve Weller. Biological effects of low-intensity radiofrequency electromagnetic radiation-time for a paradigm shift in regulation of public exposure. *Radiation Protection Australia* 34, (2017); 34, 2-6. [https://www.orsaa.org/uploads/6/7/7/9/67791943/arps\\_conference\\_aug\\_2017\\_p\\_bandara\\_v1.pdf](https://www.orsaa.org/uploads/6/7/7/9/67791943/arps_conference_aug_2017_p_bandara_v1.pdf)

6. Ritu R. Jaye et al., Effect of electromagnetic radiation of cell phone tower on foraging behaviour of Asiatic honey bee, *Apis cerana* F (Hymenoptera: Apidae), *Journal of Entomology and Zoology Studies* 5, no. 3, (2017): 1527-1527, <http://www.entomoljournal.com/archives/2017/vol5issue3/PartU/5-3-142-590.pdf>

7. David A. Ernst, Kenneth Lohmann. Effect of magnetic pulses on Caribbean spiny lobsters: Implications for magnetoreception, *Journal of Experimental Biology* 219, (2016): 1827-1832,

8. "About Transmission Arts", Transmission Arts. Wave Farm. accessed June 21, 2020. <https://wavefarm.org/ta/about>



## 2. Review of the State of the Art

Transmission art encompasses works in which the act of transmitting or receiving is not only significant but is also the fulcrum for the artist's intention. Transmission art has been defined as "a multiplicity of practices and media working with the idea of transmission or the physical properties of the electromagnetic spectrum".<sup>9</sup> This medium has been widely explored by various artists and an extensive catalog of their works can be found on the Wave Farm website.<sup>10</sup>



Figure 1. Wave Farm + WGXC Acra Studio. Photo: Anonymous.

Wave Farm is a non-profit organisation and are considered pioneers of the transmission art genre. Formed in March 1997, they were originally known as free103point9. The group participated actively in the micro-radio movement in United

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9. Galen Joseph-Hunter, "TRANSMISSION ARTS: Air that Surrounds Us", MIT Press Journals 93 (2009), 34-40, <https://www.mitpressjournals.org/doi/pdf/10.1162/pajj.2009.31.3.34>

10. "Wave Farm Archive : Site-wide Organisational Archive Search", Wave Farm. accessed June 21, 2020. <https://wavefarm.org/wf/archive>

States of America.<sup>11</sup> Their activism and advocacy efforts helped create the country's low-power FM radio service, which provided a licensing opportunity for small broadcasters operating transmitters of 100 watts or less.<sup>12</sup>



Figure 2. Scanner live at Beursschouwburg. Photo: Melanie Detry.

Using radio waves as source material was a technique often employed by British artist Robin Rimbaud. His stage name Scanner was inspired by the radio scanners he used in his recordings and live performances. His early controversial works using found mobile phone recordings and police scanners were a significant addition to the movement which is transmission art. His albums *Mass Observation* (1994), *Delivery* (1997), and *The*

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11. Joseph-Hunter, "Transmission Arts," 35.

12. "Mission and History", About, Wave Farm. accessed June 21, 2020. <https://wavefarm.org/wf/about/mission-history>

Garden is Full of Metal (1998) have been hailed by critics as innovative and inspirational works of contemporary electronic music.<sup>13</sup>

Fading Signals (Dead Air) (2014) by Canadian artist D. Burke Mahoney also utilises radio waves as source material.<sup>14</sup> This work is a culmination of scanning and recording airwaves for elusive radio signals which have supposedly been rendered obsolete by digital transmissions.<sup>15</sup> Mahoney made a single 13 minute recording using a 1956 National NC-88 shortwave receiver and this recording was the basis of the soundscape which eventually became Fading Signals (Dead Air). Mahoney embellishes the recording with additional tones and melodies which encourages the listener to form their own narrative to a story which “quite literally, appeared out of thin air”.<sup>16</sup>



Figure 3. InharmoniCity album art. Artwork: David Trulli.

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13. Robin Rimbaud. “Scanner :: Biography” Scannerdot. Scanner. accessed June 21, 2020. <http://scannerdot.com/robin-rimbaud-scanner-biography/>

14. D. Burke Mahoney, “Fading Signals (Dead Air),” January 6-10, 2014, Radius, Soundcloud, <https://theradius.us/episode47>

15. Mahoney, “Fading Signals”.

16. Mahoney, “Fading Signals”.

InharmoniCity (2008) by the Milan/Rome based duo U.S.O Project realises an urban symphony by using sounds normally hidden from our perception and revealed through unusual transducers.<sup>17</sup> In the track Girl Running, a dialogue is established between the sounds synthesised with Xenakis' UPIC and the sound outputs of invisible electronic objects.<sup>18</sup> By carrying these magnetic fields into the audible range, the sounds have been suspended, intimately researched and orchestrated in order to cross the physical borders of aural perception.<sup>19</sup>



Figure 4. Kirsten Roos performing at Radio Revolten. Photo: Kirsten Roos.

This method of sonification of electromagnetic transmissions resonates with the methodology adopted by artist Kirsten Roos. His projects *Electrosmog* (2015) and *Anti-*

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17. "Radius Sketchpad Audio: U.S.O. Project (Audio)" Archive, Wave Farm. February 23, 2013. <https://wavefarm.org/wf/archive/24w3ha>

18. U.S.O. Project - Unidentified Sound Object, "Girl Running," track 1 on *InHarmonicCity*, Synesthesia Recordings, catalogues no. SYN-002, 2008, Bandcamp

19. U.S.O. Project - Unidentified Sound Object, "InharmoniCity," June 2-10, 2012, Radius, Soundcloud, <https://theradius.us/episode26>

wave (2017) examine the silent electromagnetic transmissions that are ubiquitous today and emitted by wifi routers, bluetooth, cell phone tower emissions, etc.<sup>20</sup> Roos captures these inaudible frequencies with devices that recognize them not as information (conversations, emails, streaming), but as something similar to the unwanted sounds that were heard in early radio reception (static, whistles, sferics).<sup>21</sup>



Figure 5. Christina Kubisch with her work Cloud(2011/2017). Photo: Ecki Güther.

But the use of electromagnetic sounds in an artistic context can be most exemplified by the works of Christina Kubisch. Towards the end of the 1970s she began to use the technique of electromagnetic induction for her sound installations.<sup>22</sup> She developed a unique pair of headphones with magnetic coils which enabled her to listen to

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20. Kristen Roos, “Electrosmog”, Transmission Arts, Wave Farm, accessed June 21, 2020. <https://wavefarm.org/ta/archive/works/eaf32h>

21. Kristen Roos, “Anti-wave” Transmission Arts, Wave Farm, 2017. <https://wavefarm.org/ta/archive/works/r6db56>

22. Christina Kubisch, “Electromagnetic Induction”, Christina Kubisch, Christina Kubisch, Accessed November 14, 2019, <http://www.christinakubisch.de/en/works/installations/2>

electromagnetic sounds in her vicinity. This system was refined by her over a period of several decades and resulted in various sound installations since 1980.<sup>23</sup>

In 2003 she started researching on a new series of works designed for public spaces. Her research resulted in the first 'Electrical Walk' which took place in Cologne in 2004.<sup>24</sup> 'Electrical Walks' were a novel exploration of city soundscapes where the listener traced the electromagnetic sound ecologies of a specific urban environment. Information on her website states 'Electrical Walks' to be a work in progress. They are a public walk with special, sensitive wireless headphones by which the acoustic qualities of aboveground and underground electromagnetic fields become amplified and audible.<sup>25</sup>

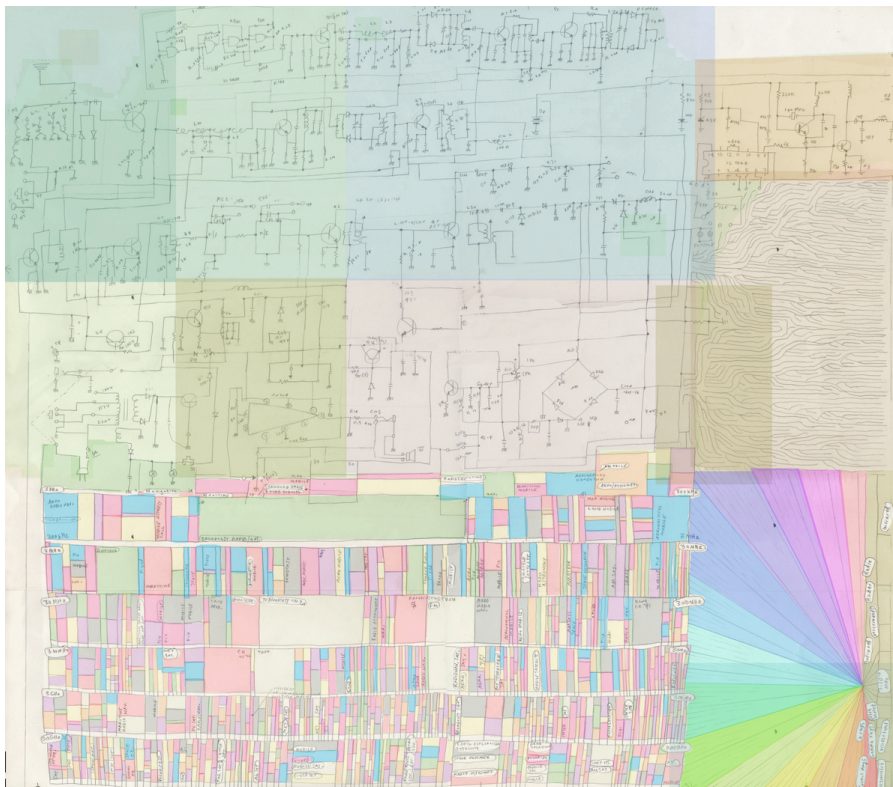


Figure 6. Wave Farm 20th Anniversary Poster. Artwork: Maximilian Goldfarb.

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23. Kubisch, "Electromagnetic Induction".

24. Christina Kubisch, "Electrical Walks", Christina Kubisch, Christina Kubisch, Accessed November 14, 2019, [http://www.christinakubisch.de/en/works/electrical\\_walks](http://www.christinakubisch.de/en/works/electrical_walks)

25. Kubisch, "Electrical Walks".

In 2011 she premiered a new installation called 'Cloud' which was also based on electromagnetic sound ecologies.<sup>26</sup> This installation is produced on-site using 2000 feet of red electrical wire which hosts a 12 channel composition that visitors listen to by wearing customised headphones. The wireless nature of these headphones enables the user to move freely in the space which in turn results in changes in the sound perceived by the user with the slightest movement of the head.

The works of these artists and collectives like Wave Farm create a historical point of reference for future artists. Transmission art as a movement engages in making the ethereal tangible through works that demonstrate a physical delineation of space through sonic or visual representation vis-a-vis the architecture of transmission and reception.

### **3. Description**

#### **3.1 Origin**

The conceptual groundwork for this project materialised in 2017 during the final year of the author's undergraduate studies at Anglia Ruskin University, Cambridge. The concept emerged from an assigned coursework which required the student to create a work of art using environmental field recordings. Research led to the discovery of Bernie Krause's work and his concept of sound ecologies. The author interpreted Krause's work and suggested an additional sound ecology which was beyond the scope of human perception, i.e., electromagnetic sound ecologies or electromagnophony. That project was exploratory in nature and resulted in the documentation of various electromagnophonies which were presented as a collection of audio recordings. After graduation this project was shelved by the author in favour of other sonic explorations.

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26. Kubisch, "Electromagnetic Induction".

On enrolling in the MMus in Music Production, Technology and Innovation program at Berklee College of Music, Valencia the author was required to formalise a thesis idea. First consideration was given to a noise album which would use recordings of various electromagnophonies as source material. After consultations and discussions with thesis supervisor Pierce Warnecke the project was formalised as a sound art installation. The installation would be presented as a physical structure in the shape of a black wooden cube. Eight speakers were to be positioned in each of the vertices of the cube with the sound spatialised in an octophonic format. The installation would then be experienced individually by entering the cube.

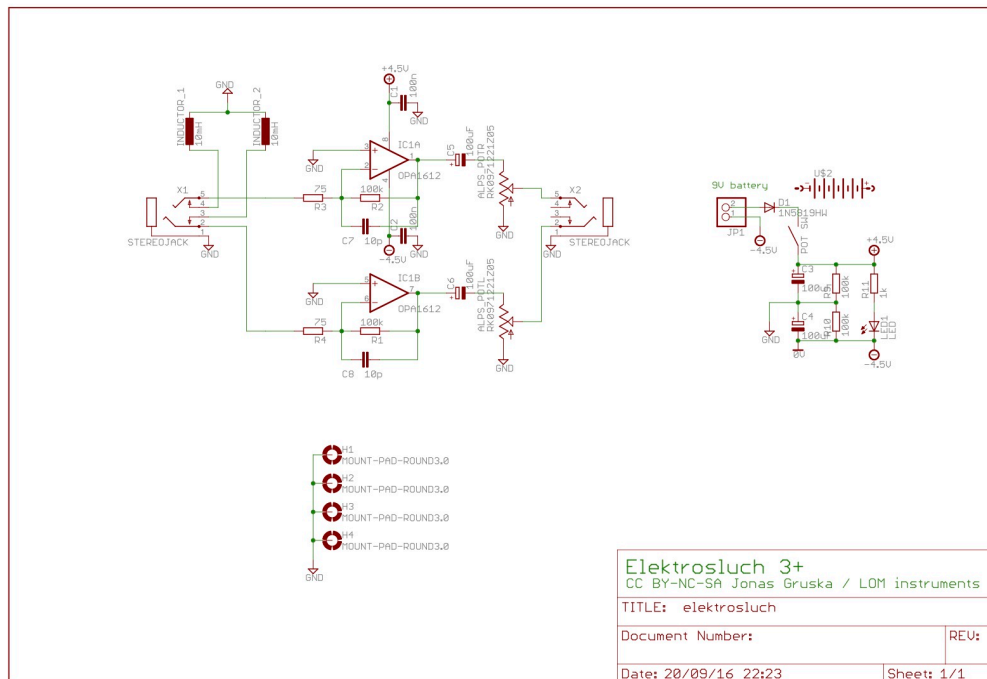


Figure 7. Schematics for EMF detector and amplifier.

### 3.2 Preliminary Preparations

A bespoke electromagnetic field (EMF) detector and amplifier was built based on the open source schematics of the Elektrosluch 3+ originally designed by Jonas Gruska.<sup>27</sup>

27. Jonas Gruska, “Elektrosluch-3-Plus”, LOM-Instruments, Jonas Gruska, September 20, 2016. [https://github.com/LOM-instruments/Elektrosluch-3-plus/blob/master/hardware/elektrosluch\\_schematic.pdf](https://github.com/LOM-instruments/Elektrosluch-3-plus/blob/master/hardware/elektrosluch_schematic.pdf)



This device was used to detect and amplify changes in electromagnetic fields with the amplified sound recorded with a Zoom H4n handheld recorder. Recordings were made at various locations in Valencia like Plaza del Carmen, City of Arts and Sciences, the Turia riverbed, on campus at Berklee and at the author's residence. Thereafter the recordings were imported to Ableton, edited, arranged and exported as a stereo composition.

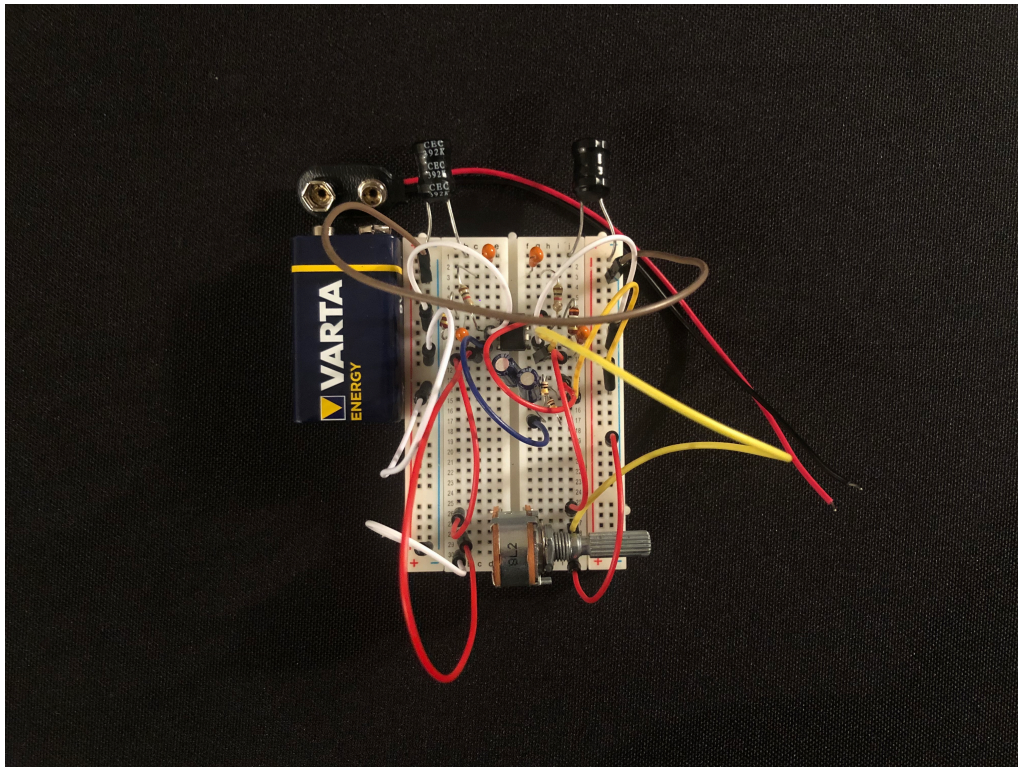


Figure 8. Electromagnetic field detector and amplifier.

Simultaneously construction plans were made for the cube in consultation with Pierluigi Barberis. The plan was to build a wooden cube with volumetric dimensions of eight cubic feet. The wooden panels were designed to be modular and detachable in order to facilitate easy transport and storage. In order to better visualise the cube, a 3D render was made in the 3D modelling software Blender, depicted in the next page in Figure 9.



Figure 9. 3D renders of the cube made in Blender.

### 3.3 Prototype #1

The stereo composition titled 'EMF Composite 2' was presented along with the 3D model of the cube for the first prototype presentation. The general feedback on the composition was that it was too abrasive, was lacking in dynamic range and it was pertinent to consider how the composition would be perceived once spatialised through the octophonic system inside the cube.

### 3.4 Amendment #1

Max 8, the visual programming language, was used to create a custom spatialisation interface. The decision to build a custom interface was based on two determining factors. The first factor was the need for generative, probabilistic and algorithmic decision making which was easily achievable in Max 8 but not so in general Digital Audio Workstations (DAW) like Pro Tools, Ableton Live or Reaper. The second factor was the need for a customisable octophonic speaker configuration because the cube shape was not a feature present in most spatialisation tools.

In order to build a custom spatialisation interface in Max 8, research was done into internal and external objects which facilitated multichannel sound. Max 8 has native multichannel implementation with the new MC class of objects. However the implemented panning feature did not account for custom speaker layouts as was required for the project. Research yielded two viable results. The first was a set of external objects developed by the Institute of Computer Music and Sound Technology (ICST) at the Zurich University of Arts.<sup>28</sup> The ICST Ambisonics tools provide a set of externals for full 3D surround audio processing. The second result was the Spat set of externals developed by the *Institut de Recherche et Coordination Acoustique/Musique* (IRCAM) in France.<sup>29</sup> The Spat externals provided a software suite for real-time spatialization of sound signals.

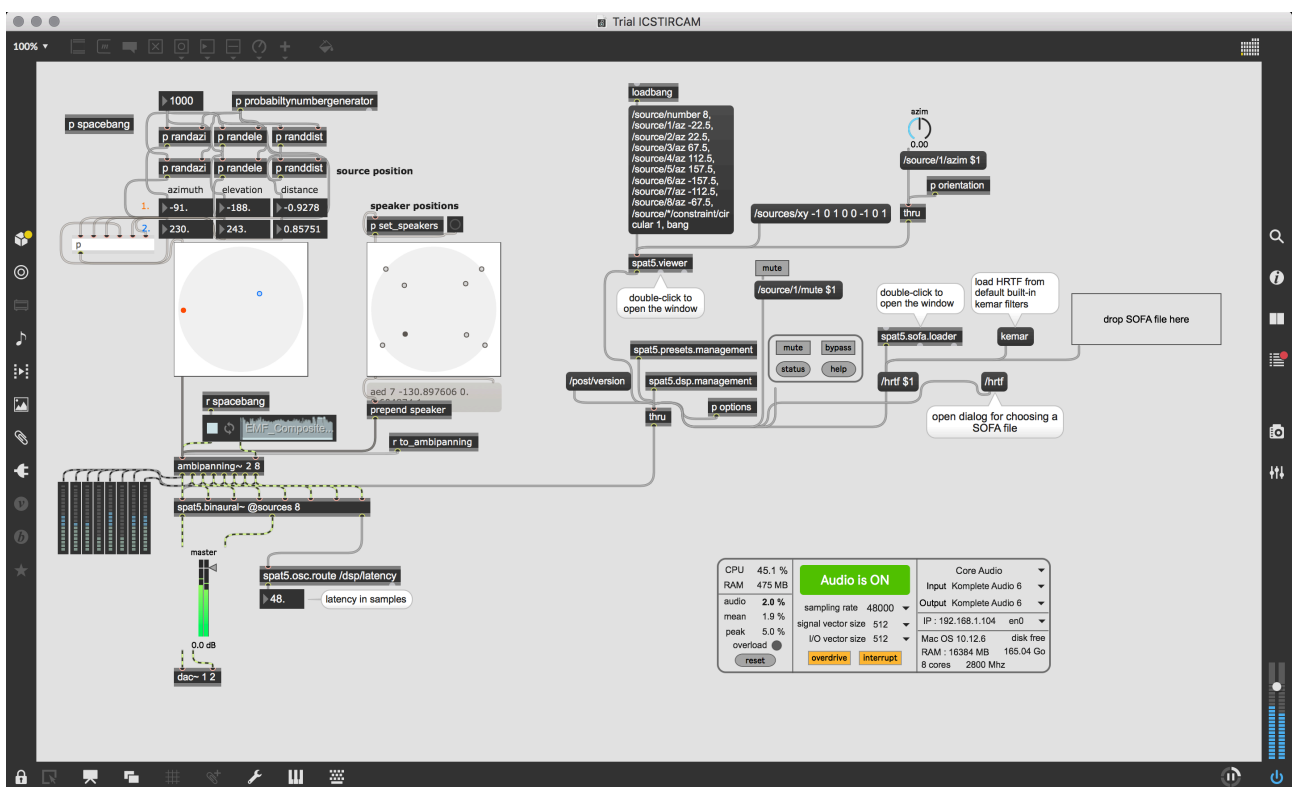


Figure 10. Max patch for multichannel spatialisation and binaural encoding.

28. Zurich University of Arts. “Downloads: Ambisonics Externals for MaxMSP”, Research, accessed June 21, 2020. <https://www.zhdk.ch/en/research/icst/software-downloads-5379/downloads-ambisonics-externals-for-maxmsp-5381>

29. Institut de Recherche et de Coordination Acoustique/Musique. “Spat”, Forum, accessed June 21, 2020. <https://forum.ircam.fr/projects/detail/spat/>

The Max patch in Figure 10. uses a combination of objects from both set of externals. The `ambipanning~` object is used to spatialise the stereo composition into 8 channels of sound setup in a cubic octophonic configuration. These eight channels are then encoded into a binaural format with the `spat5.binaural~` object. This was a crucial requirement as it enabled playback of a multichannel composition over a stereo headphone output. This was necessary as easy access to a multichannel speaker setup on campus was not always possible and a multi-speaker setup at home was also financially improbable.



Figure 11. Testing on a quadraphonic setup in the AML.

After prototyping the Max patch with the binaural output, the patch was tested with a quadraphonic speaker layout, as depicted in Figure 11. The speakers used were the KRK speaker pair in the Applied Media Lab (AML) and an M-Audio speaker pair reserved from the Equipment Room (ER). Initial tests proved to be moderately successful even though the testing conditions were not ideal. The speakers were from different manufacturers and had different frequency responses which affected the tonal quality of the audio. The

directionality of the sound was also compromised as the speakers, although placed equidistant from each other, could not be placed at the same height.

Concurrently progress was made on the physical build with the required wooden materials, metal hardware and electric circuitry being purchased. The venue for the build was being finalised with quotations received from Oceano Naranja Fab Lab and Curiosibot. An application to showcase the installation at En Vivo had also been completed and efforts were being made to reach out to other possible venues. However, shortly after the delivery of the construction materials, a state of alarm was declared in Spain due to spread of the COVID-19 virus. This connoted that access to a build site would not be possible until the state imposed lockdown had been lifted. This also implied that public spaces would remain shut for the same duration of time thereby signifying the futility of a physical installation.

### **3.5 Prototype #2**

The binaural version of the eight channel composition titled 'STTC-VAR-1' was presented and general feedback received was positive. The spatialisation effect had translated well onto headphones which was a positive sign. The main concerns raised were about the virtual presentation of the project. The possibility of a virtual reality (VR) showcase was negated by lack of sufficient time and the steep learning curve of a VR development platform like Unity.

### **3.6 Amendment #2**

After consulting supervisors Pierce Warnecke and Marta Verde the decision was made to focus efforts on perfecting the multichannel composition while also investigating methods of implementing an online installation. The change in the medium of delivery of

the installation led to some significant changes in the methodology. The decision to use Max as the main compositional tool was influenced by the need for a customised octophonic speaker configuration which was a requirement for the physical installation. Since that was no longer necessary, it opened up a new set of possibilities for creating spatialised compositions.

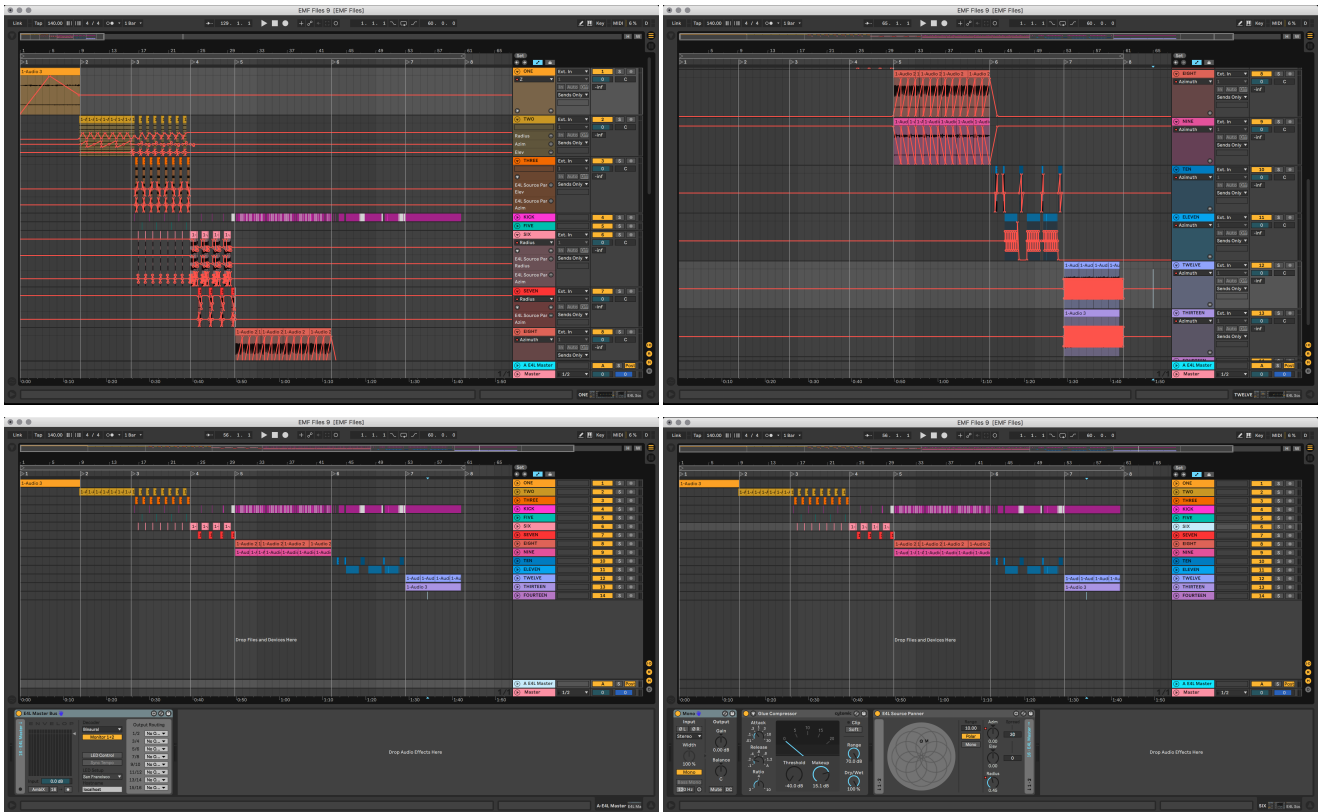


Figure 12. Ableton Live session with Envelop for Live ambisonic spatialisation tools.

In order to explore these possibilities the entire composition was first reworked in Ableton Live to achieve a complete new form and narrative. The resultant composition was spatialised in Ableton using the Envelop for Live (E4L) set of Max for Live (M4L) devices which utilises objects from the ICST Ambisonics Tools package.<sup>30</sup> Since there was no longer a limit placed on the number of channels the composition was spatialised using third order ambisonics which uses sixteen channels of audio. The resultant ambisonics file was encoded using the B-format ambiX ambisonic audio file format. This ambisonic audio

30. Envelop, “Envelop for Live Software”, Software, accessed June 21, 2020 <https://www.envelop.us/software>

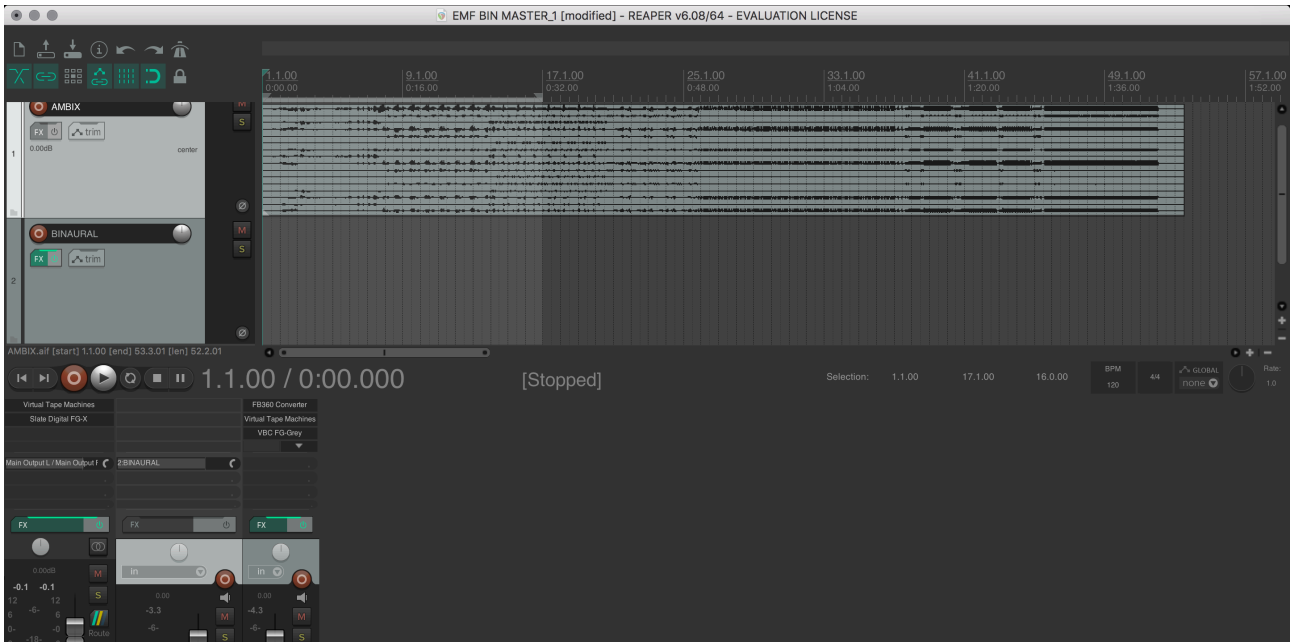


Figure 13. Reaper session for ambisonic to binaural transcoding.

file was imported to Reaper (refer to Figure 13.) in order to use the FB360 Converter to create a binaural audio file titled STTC-VAR-2.

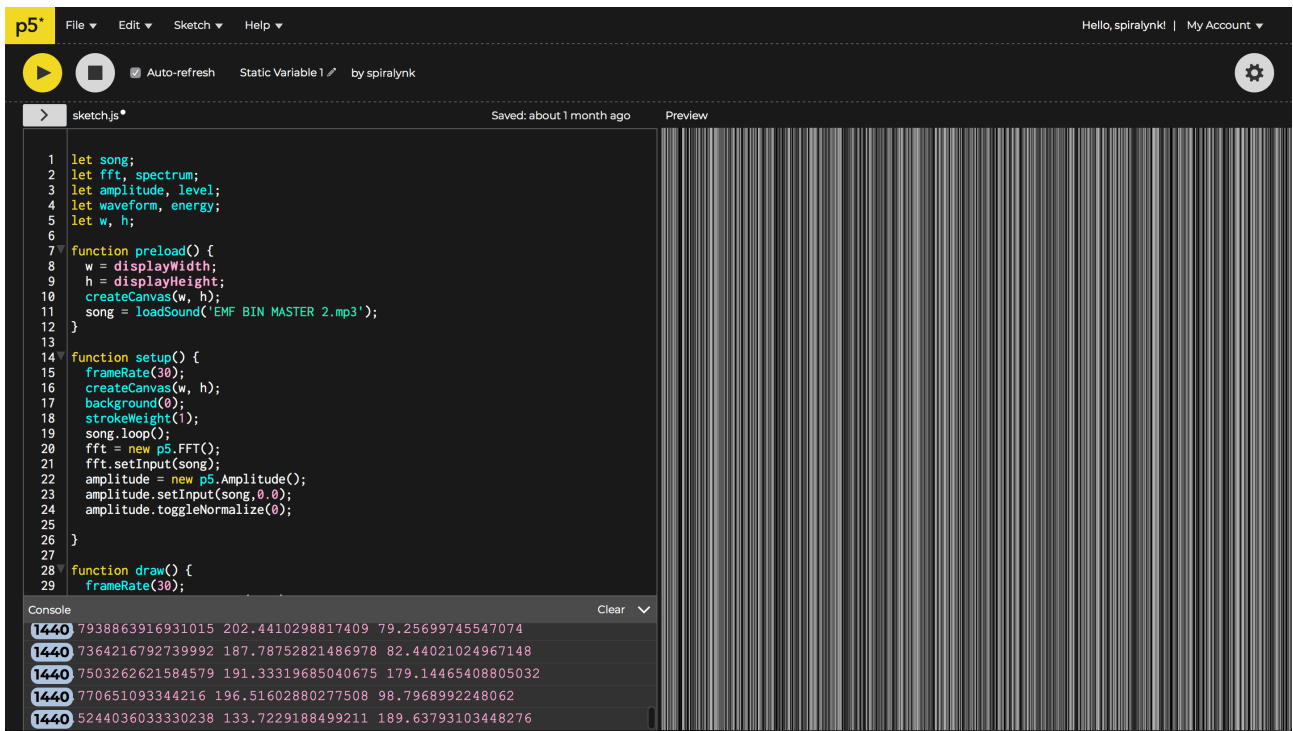


Figure 14. Audio reactive p5js sketch.

Simultaneously, while investigating methods of implementing an online installation, supervisor Marta Verde suggested using p5js as a visual compositional tool. p5js is a

Javascript library and is based on Processing which is an open-source graphical library and integrated development environment (IDE) built for electronic arts, new media art, and visual design. Figure 14. depicts the p5js IDE wherein the program being displayed is an audio reactive sketch which uses the amplitude and frequency of the audio to vary the amount as well thickness of the black and white vertical lines.

### **3.7 Prototype #3**

Two contrasting ambisonic compositions were presented as binaural mixes titled STTC-VAR-1 and STTC-VAR-2. The compositions were generally well received by the jury panel and the peer reviews were also positive. The binaural mixes also translated accurately amongst a wide group of listeners. The audio-reactive visuals in p5js illicit an underwhelming response thus requiring further improvement. The concept for the final deliverable product was also rapidly becoming clear.

### **3.8 Amendment #3**

#### **3.8.1 Static Variable**

The project was no longer a solo work of art. Instead it was the first in a series of intertextually connected, multimedia artworks, focusing on electromagnetic emissions and transmissions as the subject of interest - An Electromagnetic Nexus. The overarching body of work was to be titled Static Variable and would be presented as a website designed by the author.

#### **3.8.2 Blackscreen**

The first project in the series would be Blackscreen - two contrasting ambisonic compositions presented binaurally and sequentially. The compositions would be accompanied by audio reactive visuals. The videos would be hosted on the Static Variable



website under it's own webpage. The second project in the series would be Blackbox - a sonic art installation as envisioned before. However it would be possible to realise this project only after the complete rescinding of the state of alarm due to reasons addressed in Amendment #2.

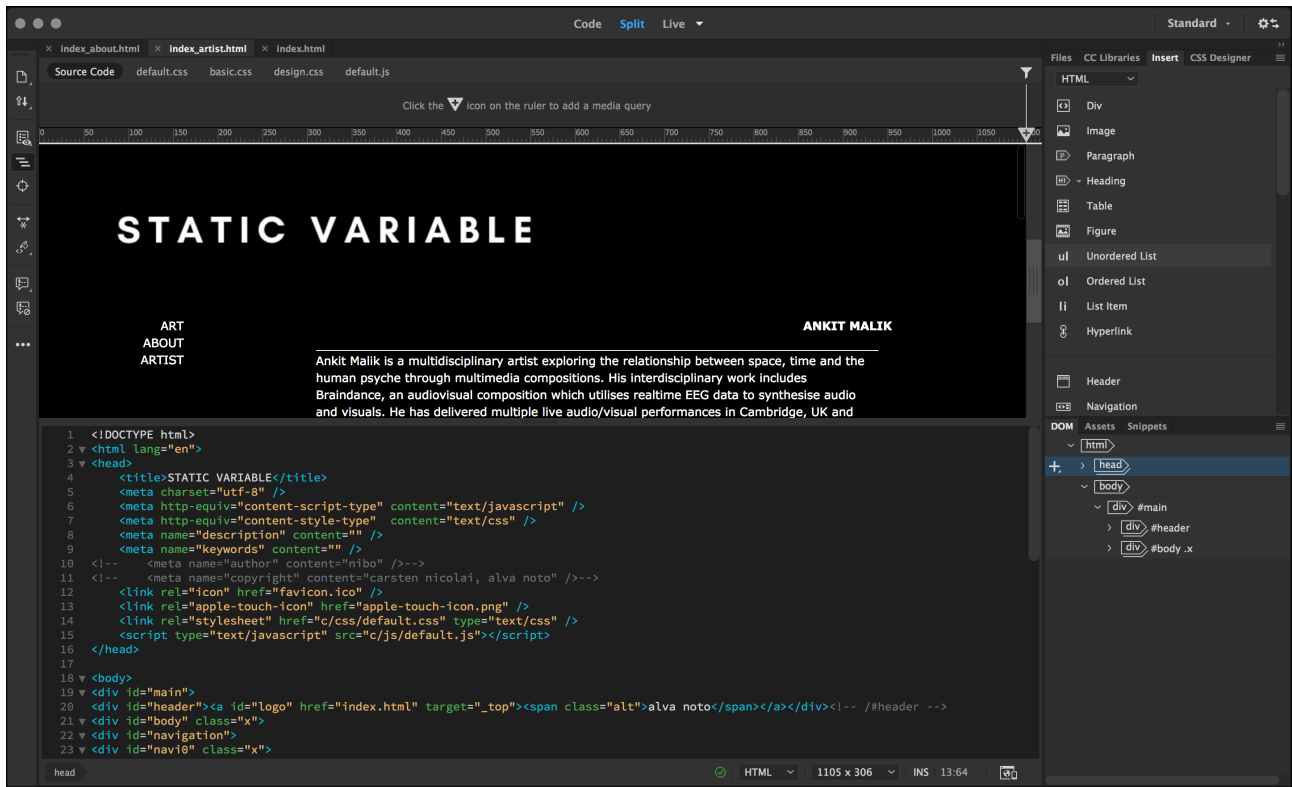


Figure 15. Adobe Dreamweaver in split view mode viewing the artist page.

The website design was a significant aspect of the project as the website itself was a deliverable. Thus choosing the right platform to build the website was an important decision to make and would be based on certain deciding factors. First of which was ease of use since website design was not a pre-existing skillset for the author. Second factor would be the ability to edit the html and css code as this would allow deeper editing options. The third factor would be affordability. These options guided the decision to create the website with Adobe Dreamweaver.<sup>31</sup> The code view, design view and split view features of the software facilitated ease of use while also informing the author's knowledge of html and css coding paradigms. Access to the code allowed for deeper editing and

31. Adobe, "Adobe Dreamweaver", Products, accessed June 21, 2020 <https://www.adobe.com/products/dreamweaver.html>

design options. Dreamweaver being bundled as a part of Adobe Creative Cloud meant that there was minimal expenditure as it was already owned by the author.

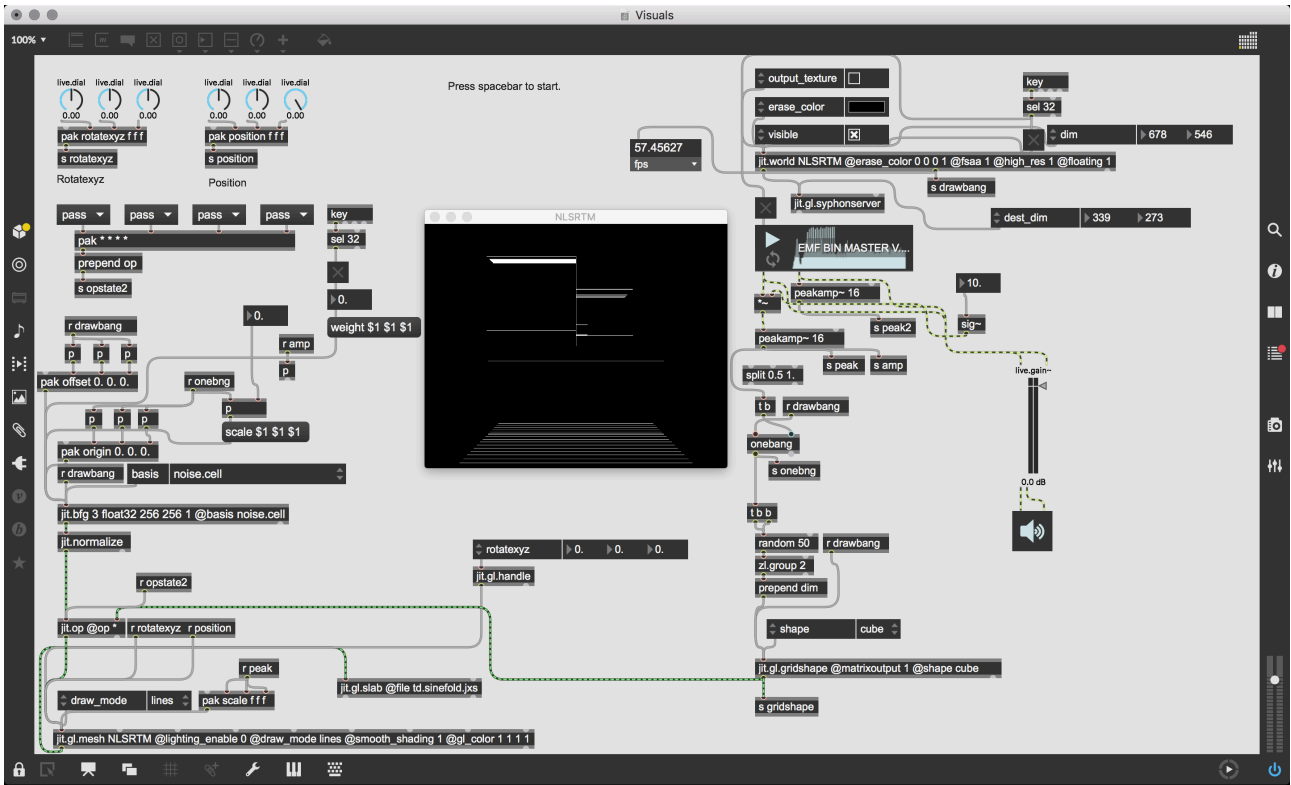


Figure 16. Max patch utilising Jitter for audio-reactive visualisation.

Previously the software p5js was used to create the visuals however the results were not satisfactory. Thus a decision was made to create the visuals using the Jitter aspect of Max 8 since the author had significant experience with the Jitter paradigm. The aesthetic chosen was a minimalistic approach using lines to create seemingly irregular patterns. This would be achieved by creating a video matrix formed from the multiplication of a matrix created by the jit.gl.gridshape object (shape attribute set to cube) with the matrix output by a jit.bfg object (basis attribute set to noise.cell). Specific attributes of the jit.bfg object like basis, offset, origin and specific attributes of the jit.gl.mesh object like scale would be modified by data gained from the amplitude analysis of the audio file thus making the visuals audio-reactive. Although the patterns would appear to be seemingly

random, they would actually be alluding to a cubic structure referencing the upcoming physical installation, Blackbox, thereby creating an intertextual reference.



Figure 17. The home page for the website.

The next step was to acquire a suitable domain. The domain [staticvariable.com](http://staticvariable.com) was available but was not an affordable option. However [staticvariable.org](http://staticvariable.org) was an affordable option and is in the process of being acquired. The evolution of the project from an album idea into an intertextually connected nexus of multimedia installations was complete. It would be available online to engage in an ongoing commentary on the omnipresent nature of electromagnetic wave.

#### **4. Innovative Aspects**

Static Variable is an interdisciplinary project which lends itself to the artistic pursuit as much as it does to scientific discovery. Science informs the process of conceptualising the project, gathering information as well as source material and building customised devices, both hardware and software. Artistic choice guides the process of visualisation, sonification and design aesthetics. The combination of both creates a unique nexus of artefacts which engage with the artistic movement of transmission arts, the scientific

understanding of electromagnetic emissions and binaural sound along with a minimalistic approach to design and visual work.

Although projects based on electromagnetic emissions exist, they seldom also utilise ambisonics and binaural audio. This project is intriguing as it combines the two fields of study in order to create a unique experience. This amalgamation leads to the an innovative artefact which is unique amongst it's contemporaries. The uniqueness results from the combination of ambisonic technology with transmission art in order to create a multiverse of interconnected artwork. Static Variable can be assessed on the merits of it's individual components as well as the sum of its parts.

## **5. New Skills Acquired**

The fulfilment of this project required a myriad set of skills. Some of them were pre-existing while others were acquired over the duration of the project. The following discussion will identify and elaborate on the new skills acquired.

Although the author was aware of the concepts behind surround sound and spatialised audio, the world of ambisonics and immersive audio was a completely new study. Enrolling in the immersive audio workshop was certainly beneficial to the cause. The knowledge acquired over the duration of this project will certainly inform future work involving immersive audio and binaural audio. This opens up pathways in sound design for VR, immersive movies and games, immersive mixes of songs as well as other installation based artworks involving spatial audio.

3D modelling in Blender was a new skill acquired over the course of the duration of the project. This skill was used to create artistic renditions of the physical cubic construct

which allowed for better planning and envisioning. The knowledge gained will be useful in future projects for creating 3D models for prototyping as well as design work.

Working with Adobe Dreamweaver for website design helped in acquiring the relevant skills as well as a robust understanding of code-based (HTML and CSS) web design. This is a crucial skill which was acquired over the course of the project. The knowledge acquired will inform future decisions in website building. Further exploration could also open up an extra revenue stream.

The final and perhaps the most valuable skill acquired was the experience of conceptualising, organising, pursuing and completing a large-scale project with most of the work done solo. Although the guidance provided by the supervisors and other faculty have proven to be priceless, the project was mostly self-directed and self-regulated. This meant the maintaining of strict deadlines and personal discipline, skills which are perennial.

## **6. Challenges**

### **6.1 Unexpected**

The major unexpected challenge faced was the national lockdown imposed by the government of Spain in order to curb the spread of the COVID-19. The lockdown resulted in a complete change of perspective with regards to this project. Prior to the lockdown this project was destined to be a singular artefact. Now the project has taken a completely different shape and is more of a cohesive body of work with major scope for future developments.

The lockdown ensured that the physical build could not be completed even though the contraction materials had already been acquired. The lockdown also meant that public

spaces like festivals or galleries would remain closed for general safety. In order to circumvent these issues the entire focus of the project was shifted from a physical installation to a online one thus negating the adverse effects of the lockdown.

The lockdown also created a financial challenge for me and my family. Our main businesses in Kolkata, India are in the travel sector. A national and international lockdown ensured that business came to a complete halt. The result was a lot of difficult choices and sacrifices which were made over the course of the duration of the project.

## **6.2 Expected**

One of the expected initial challenges was the woodworking itself since that was not a pre-existing skill. In order to overcome this challenge consultations were held with Pierluigi Barberis who had experience with woodworking as well as building installations. Plans were drawn up and 3D models were created in Blender to help the process. Eventually these plans were not utilised as the lockdown resulted in the physical installation being eschewed for the online version. However there skills will be required in the future and to over come that woodworking lessons will be taken in the future.

Storage was another significant challenge. Since the Palau and Berklee did not have access to space where the installation could be stored during the building stage, it was necessary to locate an external solution. Thanks to Marta the Fab Lab at Oceano Naranja became an option. The other option was to build at Pierluigi's workshop. Eventually these plans were not utilised as the lockdown resulted in the physical installation being eschewed for the online version.

Since the source material for the audio was very quite textural and noise-based the resultant compositions also turned out to be similar in nature. Spatialising noise based audio content proved to be a unique challenge. The dense nature of the sound meant that the audio had to be spatialised with slow almost glacial movements at some points in the composition. Panning the sound too rapidly or erratically resulted in a loss of spatial information, the brain was unable to keep track of the movements. These challenges were addressed with compositional decisions as well as sound design decisions.

## **7. Future Ramifications**

### **7.1 Blackbox**

The immediate concern after the website goes live is to start preparations for Blackbox. This necessitates the presentation of the full concept of Static Variable to galleries and artist residences for their consideration. This would increase the likelihood of receiving grants and funding which would enable the project to fund itself. The residency programs at Wave Farm and Banff Centre are prime choices.

### **7.2 Blackbox Remote**

The second pathway involves the completion of Blackbox as part of a doctoral research project. This entails the adaptation of this paper into a doctoral research proposal. The proposal would also include modifications such as the scope of realtime detection and amplification of electromagnetic transmissions. The process would involve the use of closed circuit radios with the transmitter being equipped with a modified version of the EMF detector and amplifier circuit as denoted in Figure 7 and Figure 8. These transmitters would be positioned in key parts of the city or locality where the installation is being showcased. The process would generate a different narrative with regards to the sound and the location. The audience would have a realtime perspective of the

electromagnetic sound ecologies of their location. The realtime aspect could also prove to be a more powerful tool in generating awareness about electromagnetic pollution.

### **7.3 Blackbox VR**

The third approach would involve VR technology and a virtual installation built in Unity. It would consist of a soundscape made entirely of electromagnophonies. The audience would experience the installation using a VR headset thus allowing for head-tracked ambisonic compositions.

The creation of the Static Variable brand allows for multiple iterations of the core concept to be explored in manifold ways. Artists like Alva Noto (Carsten Nicolai) and Ryoji Ikeda have used a similar approach in their artwork. Alva Noto's Uni trilogy and Ryoji Ikeda's Datamatics series are great examples of an overarching concept being modified and readapted into multiple iterations through various permutations and combinations.

## **8. Conclusion**

Static Variable is a successful amalgamation of two differing fields of study in modern music and music technology. As a project it is able to accomplish a successful merger of transmission art with ambisonics and binaural audio. This project has the potential of generating a wide body of multimedia artworks which are intertextually connected and focussed on generating awareness about electromagnetic pollution. The increasing reliance on wireless technology along with the burgeoning need for high speed connectivity only serves to assert the relevance of this project. COVID-19 has ushered in a new era of digital connectivity along with an increased need to open dialogue and generate awareness about the omnipresence of electromagnetic waves through the movement that is transmission art.



## Appendix A

**Table 2. Timeline.**

October	November	December	January	February	March	April	May	June
Conceptualising the project.	Finalising the project and drafting the proposal.	Building the EMG capture device.	Finishing the process of capturing and documenting sounds.	Acquiring materials for the build.	Changing plans due to COVID-19.	Finishing the first ambisonic composition.	Finishing the complete audiovisual artefact.	
	Starting on the Max patch which is to be used for playback and spatialisation of the recorded sounds.	Starting the process of capturing and documenting sounds.	Starting on the process of selecting the final sounds and arranging them for use with Max	Finalising build venue between Oceano Naranja and Curiosibot.	Converting project to an online format.	Finalising the first ambisonic composition.	Finishing the website and publishing for viewing and sharing.	CE presentation and defence.
	Ordering components for the EMG capture device as well as the speakers.	Continuing work on the Max patch and testing it at the AML for multichannel playback with the available speakers.	Completing the first draft of the Max patch.	Finalising the Max patch for 4 and 8 channel spatialisation.	Starting on visual aspect which was previously not a consideration or requirement.	Finishing first demos of the visuals.		
	Finishing the proposal to send out to venues.		Finalising on the venue with detailed tech riders and other specifications.			Starting work on the website.		

## Appendix B

**Table 3. Budget**

ITEM	PROPOSED	REAL	FINAL	SUBTOTALS
<b>MATERIALS (disposables)</b>				
Hard Drives	€540	€100	€100	
Memory sticks	€50	€0	€0	
Memory cards	€50	€0	€0	
				€100
<b>EQUIPMENT</b>				
<b>HARDWARE</b>				
INTERFACE (purchase)	€2,150	€0	€0	
COMPUTER (purchase)	€5,955	€0	€0	
CAMERA (rental) 10 days	€2,400	€0	€0	
ELECTRICAL COMPONENTS (purchase)	€1,000	€100	€100	
TIMBER (purchase)	€1,000	€500	€500	
METAL PARTS (purchase)	€500	€50	€50	
TABLE SAW (rental) 30 days	€800	€0	€0	
<b>SOFTWARE</b>				
ABLETON (purchase)	€750	€0	€0	
MAX 8 (subscription) 300 days	€90	€90	€90	
ADOBE CC 2020 (subscription) 300	€200	€20	€20	
DOMAIN+HOSTING	€200	€200	€200	
REAPER	€225	€0	€0	
				€810
<b>PERSONNEL</b>				
CARPENTERS	€1,000	€0	€0	
TRANSPORTERS	€1,000	€0	€0	
				€0
<b>STUDIO/WORKSPACE</b>				
BERKLEE daily x 7 days	€1,750	€0	€0	
HOME daily	€1,000	€0	€0	
WORKSHOP	€1,000	€0	€0	
				€0
<b>CATERING</b>				
MEALS cost/person x #persons x	€100	€0	€0	
				€0
<b>OVERHEAD</b>				
RENT	€950	€950	€950	
POWER	€100	€0	€0	
WATER	€25	€0	€0	
GAS	€0	€0	€0	
INTERNET	€150	€0	€0	
PHONE	€200	€200	€200	
			-	€1,150
<b>FEES</b>				
YOUR FEE	€16,325	€0	€0	
				€0
<b>TOTALS</b>	<b>€39,510</b>	<b>€2,210</b>	<b>€2,210</b>	<b>€2,060</b>

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