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Shirley E. Pegna (2013)

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Pegna, S (2013) *The Transit Of Sound And The Perception Of Sonic Phenomena* PhD, Oxford Brookes University

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The Transit Of Sound And The Perception Of Sonic Phenomena

Shirley. E. Pegna

Submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy awarded by Oxford Brookes University

March 2013

Abstract

The title of the practical research, *The Transit Of Sound And The Perception Of Sonic Phenomena*, is an inquiry into the fundamental nature of our physical environment and how sound behaves as it passes through that environment. Art works have been produced as practical research for the study and attended by visitors who could experience vibration as the manifestation of the transit of sound through different materials: air, water and solid matter.

I chose familiar settings for five of the artworks, such as sitting in a car, lying in the bath, or being in a house. I developed different ways that the visitors could engage with the works and aimed to build on the visitors' experiences of these places; heightening their perception by revealing or suggesting previously unnoticed physical evidence of the transit of sound through materials other than air.

The experience of this body of works has revealed that the central element throughout is the visitors' own imagination. In the study I increasingly chose locations to explore that required the visitors' imaginations: connecting locations that included both our expanded environment; the planet and outside the earth's atmosphere, and our own internal environment of the body.

The study provided experiences for the visitors in each of the different artworks where vibration, as the manifestation of the transit of sound through different material, informed them of the planet's physical properties as articulated through sound. The final artwork, *You Are Here*, uniquely placed the experiences in an environment whereby the visitors could go home and relate their experiences directly to the rooms of their own homes, bringing their thoughts and reflections of the planet and their relation to it 'closer to home'.

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Statement of Candidates Objectives

The objective of this three-year study has been to conduct a practice based research project into the transit of sound and our perception of sonic phenomena; the disciplinary context for this research being defined by the fields of Sound Art, Soundscape studies, and the study of Sonic Phenomena.

The study aim has been to focus on the creation of original artworks where the development of new ideas and theories create knowledge that will inform arts practice and theory. The creation of a written document with reference to previously created artwork is designed to accompany the practical body of work and be informed by the visiting public to the works. Response, and discussion from the visitors to the artworks have been central to the development of the process, and feedback in the form of written comment, recorded audio or video, has been collected and further discussed with other practice-led researchers and experts within the research community at Oxford Brookes University. There have been opportunities to collaborate with experts, for example, from the British Geological Society Field Operations and Kings College London Cosmic Ray Project in conjunction with Ilford County High School.

A three-year studentship award from the Arts and Humanities Research Council has made this research possible including the making and presenting of artworks on location and in galleries and the running of events.

Original artworks include:

2011

Audiograft 2011 - Oxford for the artworks *Ground Sound* and *Through Walls*.

The *Work in Progress* event in 2011, was hosted at the Soundfjord Galleries – London, where in a collaboration with Wajid Yaseen work was developed for *Audiograft 2012.*

2012

BEAM Festival 2012 – Brunel University London, a commission for *Through the Bathwater*.

Audiograft 2012 – Oxford, a commission for the collaborative work *Ghost Quartet* and also *Through You*.

BEAM Day (2012) workshops Brunel University, *The Festival of Desperation – Bristol*, further presentations of *Through You* and *Ground Sound* respectively.

Workshops at Firtree School and St Johns School in Wallingford, Oxfordshire were undertaken in 2012, where sound work using equipment developed in the study was investigated by children of primary age.

2013

You Are Here - in a house in Bristol, to an invited public.

Acknowledgements

My thanks goes first to Professor Paul Whitty, my supervisor and Director of Studies, who has listened, guided, supported and inspired me prior to and throughout the study, questioning and encouraging ideas and enabling projects to flourish. Thanks to Ray Lee for his sound advice and support, providing a great forum in which to share and discuss work. To Professor Shelley Sachs for guiding and encouraging me to even think of attempting the PhD; Luci Gorell Barnes and Melanie Thompson for encouraging me from the start; to Steven Cornford and Max Eastley for passing me extremely interesting ideas; Tracey Warr for inspiring the reading group to read and discuss texts I wouldn't otherwise attempt; Adrian Pawley for patiently helping me in the IT suite and Kathy Hinde's marvellous help with making the video documentation; Paul Dibley for his technical expertise: Freda Yeang for her great support with my writing skills and Lorraine Smith for dedicated help with editing the commentary.

For their expertise and enthusiasm, I must thank both Dr Paul Edmundson and John Lauchlin who gave their time to painstakingly answer my questions on geological and cosmological matters. Also to the team of collaborators from Ilford County High School: Surya Ragavan, Paul Balaji, Josh Kandola, Guy Coop, Suraj Patel and team leader Vikash Patel, who while revising for their AS exams, and inspired by Dr Edmundson, they gave their time to execute great skill in calculating and recording data from the alpha muon flux which they detected and subsequently sent on to me in Bristol for the final artwork of the study - *You Are Here.*

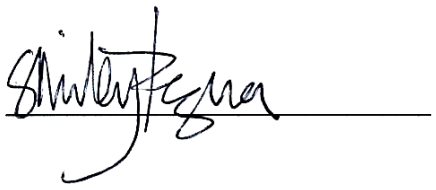
To Mike Blow, Matt Davies, Tom Pod, Georgina Rose Shire and Bim Williams, all of whom are outstandingly skilled artists and technicians and helped make fantastic bits of equipment for the project by clearly understanding the nature and essence of the work. For David Carugo, John Glasgow and Danny Bhatt for their help and expertise with investigating geophones at the Oxford Brookes Wheatley campus grounds. For Gemma Smith for giving her time, and introducing me to the deaf culture. To Tim Croston for initially inspiring me to listen to space sounds from Jodrel Bank and passing on his enthusiasm for cosmological ideas. To Wajid Yaseen for entering into an inspiring collaboration to make work for Audiograft 2012 and Soundfjord Galleries and providing much good debate and ideas. To Helen Fossi at Soundfjord Galleries - London, for kindly hosting the

public Work in Progress event and to Sarah Angliss at Brunel University and Jo Ross at Oxford Contemporary Music for commissioning and supporting work.
To Jem Finer, Lee Berwick, David Worgen, Paul Hyde, Dominic Ford, for their expert advice. To Tony Plato, Connor Ramsey and Uther Shackely Bennet, all of whom allowed me to cross-examine them. To John and Lou Skinner for very generously opening their house to artists and visitors and allowing for subwoofers and transducers to shake their kitchen and for holes to be dug in their garden To Emily Way for helping organise the *You Are Here* event in Bristol. To Charlotte Heffernan, Austin Sherlaw–Johnson, Efthymios Chatzigiannis, Jo Thomas, Sylvia Hallett and Clive Bell for their interesting discussion and advice.

Thanks finally to my patient and wonderful family: Richie Smith, Louie Pegna and Will Pegna.

Author's declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at this or any other institution.

Signature 

Printed name **Shirley Pegna**

Introduction

> ‘Or again, strive to picture yourself, with the greatest possible precision, beneath the network of streets, the tangle of sewers, the lines of the Metro, the invisible underground proliferation of conduits (electricity, gas, telephone lines, water mains, express letter tubes) without which no life would be possible on the surface.’
> Georges Perec (1999 pp.53 - 54)

Georges Perec describes what he is thinking of whilst sitting in a café in the Boulevard Saint-Germain, Paris, where he imagines what is beneath his feet. He is striving to engage with his surroundings, and to re-focus the way the reader views their surroundings; re-focusing to appreciate the surroundings in a different way. The ideas in this study are comparable to the ideas written about by Perec where he is trying to reach out in his imagination to grasp what is there or what could be there, making a link between what he knows and what he imagines.

This study examines how we understand our surroundings through sound. The practical works in this study aim to re-focus the visitors’ view of the sounding phenomena around them, engaging their imaginations so that they are able to perceive the world in a different way. The title of the practical research: The *Transit of Sound And The Perception Of Sonic Phenomena* is an enquiry into the fundamental nature of our physical environment and how sound behaves as it passes through it. It considers how it takes our experience of each moment, enhancing awareness of ourselves in relation to time, distance, mass, substance, sensation; both in technical fact and imaginative forms. In the commentary I will discuss the decisions that formed these ‘experienced moments’ for each practical artwork created for the study, where their sonic properties give both a temporal or in the moment sensation as well as an immersive one.

Unable to see the Metro, George Perec prompts us to imagine it under his feet. In imagining this scene in Paris we too question: Is it under his feet here? How far down is it? Where is it heading? We realize we probably would not have thought about the Metro if we had been sitting in the Boulevard Saint-Germain. We draw on our own imagination, our own experience of cities and subways that allows us

to recall and compare similar scenes. In this study I aim to engage with and try to understand the phenomena that exist around us, drawing on imagination and our own previous experiences in similar locations to those suggested by the art works. Unable sometimes to see the source of the sounds, we are prompted to think of them and their transit to our ears through different materials using our imagination.

The artworks were produced as practical research and were attended by visitors who could experience vibration as the manifestation of the transit of sound through different materials: air, water and solid matter. Feedback, collected from the visitors at each artwork, informed the process of the study and the ongoing methodology is commented on in the main text. An attached DVD shows a short film of each of the works described in the following chapters. The research questions guided both the devising of and reflection on the work and can be seen at the end of this introduction. To introduce the ideas on which I based my activities, I will, in the rest of this introduction, comment on the key artists and works that formed a research context, and comment on how the rationale for the equipment I chose to use relates to the nature of the practical works.

The Start of the Research

To broaden my practice as musician and composer in the realm of interdisciplinary arts, I chose to make a practical exploration of the elemental nature of sound. A key artist for this study is Alvin Lucier. I was drawn to contextual works in which he aimed to portray the physical qualities of sound. James Tenney in his writing comments that Lucier designs his pieces,

> '..so that their physical character was not obscured; other elements are made transparent to that physicality. As a result his music often has a sculptural quality to it…' (Tenney 1995 p.16)

The sculptural qualities described here include both the sound and the equipment used in the works.

Tenney reports that Lucier,

> ' ..has an abiding curiosity about "how things work",
> (Tenney 1995 p.20)

In a response to Lucier's ideas and as a precursor to this study I made a work where a rocket exploded in the sky 3.38 miles away from us; we and the onlookers heard the delayed sound of its explosion 15.98 seconds after flash. This demonstration of difference between the speed of light and the speed of sound allowed visitors to experience in 'an almost visual way' the behavior of the sound wave travelling across the space; the experience of the transit of the sound through the air (See Figure 1). My work with the rocket was 3.38 miles away, and I was interested that sound could travel a long distance. The work opened up the idea that I could question or observe the transit of sound to my ears. I started to question how else the sound could travel to me. Would the sound have travelled faster in water or through the ground for instance? How would the speeds vary travelling through materials other than air? We could track the slow sound of the rocket through air to our ears, but how could the sound be thought of travelling through water, the ground, other objects, our bodies or spaces outside our atmosphere?

Material	Speed of sound through (mp/s)	Notes
Air	343	Depending on air quality
Water	1482	Depending on water type
Ground	5,000-13,000	Depending on ground type
Speed of light: 299,709 kmp/s		
(Berg and Stork,1995 p.26) (Breithaupt, 2000 p.707)(Doyle, 1995 p.17) (Fullick, 1994 p.579)		

Figure 1 - Speeds of sound

On my visit to Hartland Magnetic Observatory (HMO)(British Geological Survey, 2013) to see a seismometer and learn just how far and fast sound could be picked up as it travelled through the ground, I found I was required to imagine the great distances the subterranean sound travelled, through and under tectonic plates and ocean beds and mountain ranges. Like the,

> '…tangle of sewers, the lines of the Metro, the invisible underground proliferation of conduits…,'

described by Perec (above), the course, speed and direction of their travelling was beyond my sight. I found when visiting HMO that technology could open up possibilities for the study, by providing experiences with equipment I couldn't otherwise have had, and could provide an extension of my understanding, making a link with what I know, what I have experienced and what I can imagine. Coupled with my imagination, different sounds and vibrations would make it possible to map a different auditory territory, expand and re consider my surroundings.

On my visit to HMO I gained an understanding of the field. For example:

- Sound or pressure waves in the ground travelled so much faster than the speed of sound through air. (See Figure 1).
- Sound waves were physically long and a 16m length wave resonated at a just audible 21.43Hz. (Berg and Stork, 1995 p.58)
- Seismometers can pick up vibrations from seismic activity thousands of miles away, sometimes right through the planet. (Interview John Laughlin, 2011)
- To find out where the wave is coming from it is necessary to take comparative readings, using the method of triangulation, from other nearby stations. (Interview John Laughlin, 2011)

Through the use of technology, audible and inaudible sound waves could form a part of my interest, and that both sonic and tactile sensations could be part of my artworks. This came about because I saw that a representation of inaudible sound as seen on a computer screen, although interesting, did not give a visceral experience of this sound. The real-time data in graph form could only convey a visual experience of the activity picked up by the seismometer.

Mark Bain and Toshiya Tsunoda work with sound and tactility. In Bain's *Trembling Structures* (Bosma, 1999), visitors touch the building shaking with vibration from low frequency sound waves. In Tsunoda's *Monitor Unit for Solid Vibration* (LaBelle, 2008 p.238), he focuses on minute vibrations in built structures. Both of these works impacted on my understanding. Brandon LaBelle comments,

> 'What Tsunoda's subtle invasions reveal is vibration as a material itself.....,' (LaBelle, 2008 p. 239)

This comment encouraged me to think of artworks that could have vibration at their centre, where it was possible to feel the work as well as hear it. Therefore, when I listened to *Earth Sounds*, pre recorded seismic sounds speeded up by sound artist John Bullitt (Bullitt, 2007), the absence of vibration and the lack of low frequency sound, caused me to feel removed from the experience of the immediate and tactile nature of audible and inaudible low frequency sound waves. What was missing for me was the tactile vibration, the material of the work. I thought the facts of the work, although accurate, did not convey an experience or sense of that place.

In Caleb Kelly's book *Sound*, Seth Kim-Cohen discusses *Sonic Pavilions* by Doug Aitkin (Kelly 2011 p.219). This is a realisation of Bruce Nauman's 1969 work *Untitled* (Kelly 2011 p.186). Reading this account allowed me to reflect on the relationship between Aitkin's work and the work in this study. In common with Aitkin's work I use microphones in the ground to amplify sound that we are generally unable to experience. The way in which equipment is used creates the idea that the works are of a scientific nature. To define accurately what Kim-Cohen means by the difference between an artwork and the –

> '…didactic monologue of a science exhibit'
> (Kim-Cohen in Kelly, 2011 p. 221)

he states that there is a 'play' between the physical manifestations, or the 'material strata' of a work, and the concepts it introduces.

> 'Meaning is only ever produced by the frictions between things. Like every medium sound derives its meaning from context, from intertextuality, from the play of difference in its conceptual and material strata. It is the worldly rather than the earthly that presents the possibility of meaning.'
> (Kim-Cohen in Kelly, 2011 p.221)

We experience and imagine the sound in the ground in both Aitkin's *Sonic Pavilions* and my *Ground Sound* (2010). Kim-Cohen argues that Aitkin is suggesting what he should think of the experience; it is being described as the revelation of a,

> '..mysterious and living dialogue'. (Kim-Cohen in Kelly, 2011 p.219)

I suggest that *Ground Sound* gives an experience of the sound through the ground, but does not qualify it by specifically saying what it is the sound should mean. Kim-Cohen makes a distinction in his argument, between the idea that he will have an experience that he can decipher himself, and the idea that it will be an experience (Aitkin suggests) to -

> ' ..unlock the coded mystery of the deep'.
> (Kim-Cohen in Kelly, 2011p. 221)

Kim-Cohen describes the sound in its context giving ' possibility to meaning', rather than being told directly what it should mean. In this study, decisions were made to present the works in different ways to bring about possible individual associations for each visitor to the work and provide a 'context'. Important to these decisions were, for instance, the language in the title, the amount of interaction the visitor might have with the work, the sound or vibration created and the understanding the visitors could have of the location or setting with the equipment used. The chapters in the commentary describing the works outline these decisions.

Technology

The technological objects used in the works are 'listening in' to the ground, water and air. The equipment used in these art works, was chosen for its ability to make sounds that are usually inaudible audible and increase our powers of perception. The experience for the audience is shaped by the relationship between the visual culture of the scientific devices and the sonic experience of their output. To probe and to question if there is anything there or not, like bionic extensions to our human ears, they listen through the earth and up into the atmosphere. I use geophones, hydrophones, long-range microphones, contact microphones, scintillator detector boxes, sub woofers, head phones and transducers where sound can be sensed through solid materials, water and air, in and outside our atmosphere. A large part of my methodology was concerned with finding the right equipment to use in different locations and to understand the basic behaviour of the signals I was interested in amplifying.

The tools themselves gather data – the data of sound waves, and for the work *You Are Here* (2013) the data of cosmic rays. Our experience, as onlookers, shows that we are looking at technologically precise instruments that might measure this data, we might assume for its analysis. Here the physical manifestations of the work

produces context on the one hand where we see objects that convey a possible scientific analysis, and on the other the other hand, we receive an experience of the sound or vibration that we as listeners do not necessarily measure accurately but associate with previous experiences, taking in the concept of its transit. Each individual work in the study requires the visitor to balance their views of these aspects as Kim-Cohen describes,

> '…from intertextuality, from the play of difference in its conceptual and material strata.' (Kim-Cohen in Kelly, 2011 p.221)

As an artist and not a scientist, I have been asked if I know what I am presenting can be validated. The filtering of sound, via technology to our ears, gives a version of that data as sound, depending on the technology used in that situation, in much the same way that a Stradivarius violin renders a musical phrase differently from a cheaper model. The equipment or technological objects collect and filter the sounds but do not measure or plot them. The works in the study aim to change our perception of our surroundings, expanding the reach of our hearing, extending the auditory map further than the limitations of our human ears. For instance *You Are Here* (2013) makes audible the low frequency sounds of the movement of neighbours and traffic from streets away.

The cultures of 'technology' and 'nature' are brought together by the works in the study. Douglas Kahn comments that sound artist and thinker, Pauline Oliveros, refers to this notion as the 'Sonosphere', alluding not only to sound, but more broadly the energies that instigate signals associated with sound. Douglas Kahn describes them as,

> '..a barrage of energies including the magnetic, electrical, electromagnetic, geomagnetic, and quantum, as well as the acoustical.' (Kahn, 2013 p.174)

Further to this Kahn compares Oliveros's ideas to R. Murray Schaffer's narrower notion of 'soundscape', indicating that,

> 'It resonates among personal and interpersonal, musical, earth, and cosmological scales informed by physics and metaphysics. Furthermore, unlike soundscape, there is no stigma of technology arising from a moral chasm between nature and technology' (Kahn, 2013 p.174)

I became interested in the transition between energy and soundwaves, including the behaviour of radio waves, microwaves, and in the case of telescopes or optical sensors, light waves and radiation. My visits to Jodrell Bank Observatory (Manchester University, 2013) and The Royal Society Summer Exhibition (2012), led me to collaborate with the head of Physics at Ilford High School and the Corus Project (Kings College London, 2013), described later in Chapter Five.

Perception and Participation

Our perception of sound is explored in the work of Pauline Oliveros, and particularly in her 1998 work *Ear Piece* (Lely and Saunders, 2012 p.289). In this work she encourages the participant to observe themselves and how they are thinking of sound. In making a distinction between two modes, 'hearing' and 'listening' to sound, she heightens our perception of the different ways we receive sound.

> 'A philosophy and practise […] that explores the difference between the involuntary nature of hearing and voluntary selective nature of listening. The result of the practice cultivates appreciation of sounds on a heightened level, expanding the potential for connection and interaction with one's environment, technology and performance and others in music and related arts.' (Oliveros in Lely and Saunders, 2012 p.290)

The territory of Oliveros's work where she gives us the opportunity to look at ourselves perceiving sound, led me to explore, not only the imagined geographic journeying of sound, but to challenge our usual habit of hearing. In this study I investigate listening through the body as an unusual way of perceiving sound and that drawing comparisons with what we may assume as the normative mode of hearing through the ears. The body as a material: bone, tissue, air and liquid, conducts sound to the inside of our ears, and if we choose to pay attention to this it will expand our perception of sound. The work in this study asks us to recall our own normative habits of listening and to compare these to the expanded perception of sound as it travels through the body, as described in the work *Through You* (2011) Chapter Four.

Our imagination is brought to bear if we are concerned with what we can't hear. Being aware of the human ear's limitations creates a situation where we can be

more aware of the sound worlds we can't hear and that other living things such as fish, insects, reptiles and mammals for example bats, elephants and whales can. This creates an idea that our own senses, hearing, sight, smell and touch, give us but a part of the many energies we might sense existing in a larger universe of the signals we can't as humans, physically receive. I found out more about the function of our ears at Supersonix (2012) in London, David McAlpine Professor of Auditory Neuroscience (UCL, 2014) outlined the causes of hearing loss and the hearing abilities of the human ear, and Jacob Kirkegaard described characteristics of functions of the ear that extraordinarily produce tones, when explaining his work *Laborithitis (*Kirkegaard, 2008). Being aware of my own listening, and the signals coming to my ears that I can and can't hear, allowed me to think about a ' sonic possible world,' a phrase coined by Salome Voegelin (Voegelin, 2014), and opened up the possibilities that my imagination was key to this larger universal picture, sonic or otherwise.

The works in this study draw on our experience of sound. In five of the artworks, I investigated domestic or everyday situations, for example sitting in a car, lying in the bath, standing in a kitchen or looking up out of the attic skylight. I develop different ways that the visitors can engage with the works and aim to build on the visitors' experiences of these places, engaging their imaginations by extending their perception of listening and revealing previously unnoticed physical evidence of the transit of sound through materials other than air. Here is Kim-Cohen's revelation of 'meaning' via 'context' in our recalled experiences; the 'meaning' and 'context' starting with and stemming from familiar places in our daily lives.

My conviction that sound is a sense that connects us to ourselves in our environment is described well by Salome Voegelin,

> '.. its invisible mobility, in its sticky and grasping liquidity there is something that augments, expands, and critically evaluates how we see the world and how we arrange ourselves to live in it.' (Voegelin, 2014 pp.2-3)

Lastly, each of the pieces I have discussed in the Chapters One to Five, comment on the relevant research questions (below). I was simultaneously engaged in exploring ideas arising from the responses to these questions via different investigations, and those investigations moved forward at different times. My methodology takes this into account: researching and developing equipment,

talking to experts, attending conferences and visiting sites to test equipment, creating works, gathering documentation and exploring the feedback from the visitors to the works. The commentary connects my practice, research questions and creative relationships with the materials and experiences of the study, and contains both evidence of data and artistic reflection.

Throughout the commentary, the sound artworks respond to the questions, and in them are explored the perception of space and the impact of the work on the imagination of the visitors to the work. My engagement with the issues expressed in the introduction is the context for my study and is what has informed these specific research questions and my response to them. It is my own critical engagement with the sounding world – the 'Sonosphere.'

Research questions

1. How does our experience of sound change in relation to the materials through which it is transmitted?

2. How do listeners develop an understanding of the transit of sound from source to perception?

3. How can the physical properties of sound become manifest through the production of Sound Artworks?

4. What is the existing context in Sound Art Practice for the study of Sonic Phenomena?

Chapter One – Vibrations on the Skin of a Drum

> 'Just as the human body is sharply bounded by skin, temperature differences, blood chemistry, and a calcium phosphate skeleton, so is earth distinguished from its surroundings by its persistently anomalous atmosphere, its steady temperature, and its unusual limestone and granitic rock.'
> Lyne Margulis (1998 p.31)

In the same way that the biologist Margulis compares the earth to the human body, after the experience of my initial investigations I started to see the surface of the earth as a reactive layer or even as a skin. In this chapter I describe how this is realised in the artwork *Ground Sound* (2011).

I set out to pick up sounds from the ground via a geophone (SM24), amplifier and subwoofer. I was keen to develop a system that could powerfully amplify the vibrations in order to explore and illustrate their strength, and was also interested in a system that could be mobile initially so I could test and show the sounds from the ground in different places. I found that the sound systems designed for cars would work from a battery. This allowed for movement away from the power source in a building and being designed to show off their owner's sound system and sound collection, would function powerfully at high decibels. Having previously used a Genelec Powered Speaker to hear sounds from the ground when diffusing sounds through a pipe, I now tried a car amplifier (3000W TL-1023) and 12 inch subwoofer (3000W Tl-1121) designed to be powered by a car battery. Because of the unpredictable nature of the signals from the ground, I learned that it was advisable to have a pre-amp (Sound Devices MP-1) to boost the signal from the geophone to the amplifier (See figure 2).

The Car Experience

The geophone was placed so that a person sitting in the car would hear live sound and experience vibrations from the ground as they were diffused into the car via the geophone and amplification equipment. While being able to hear sound picked up from the geophone, they would also be able to see what was affecting the ground next to the geophone. The car sound system and geophone allowed the visitors to see that the sound was live and not recorded as they could match the change in sound, caused by the impact of peoples' footsteps or the nearby traffic,

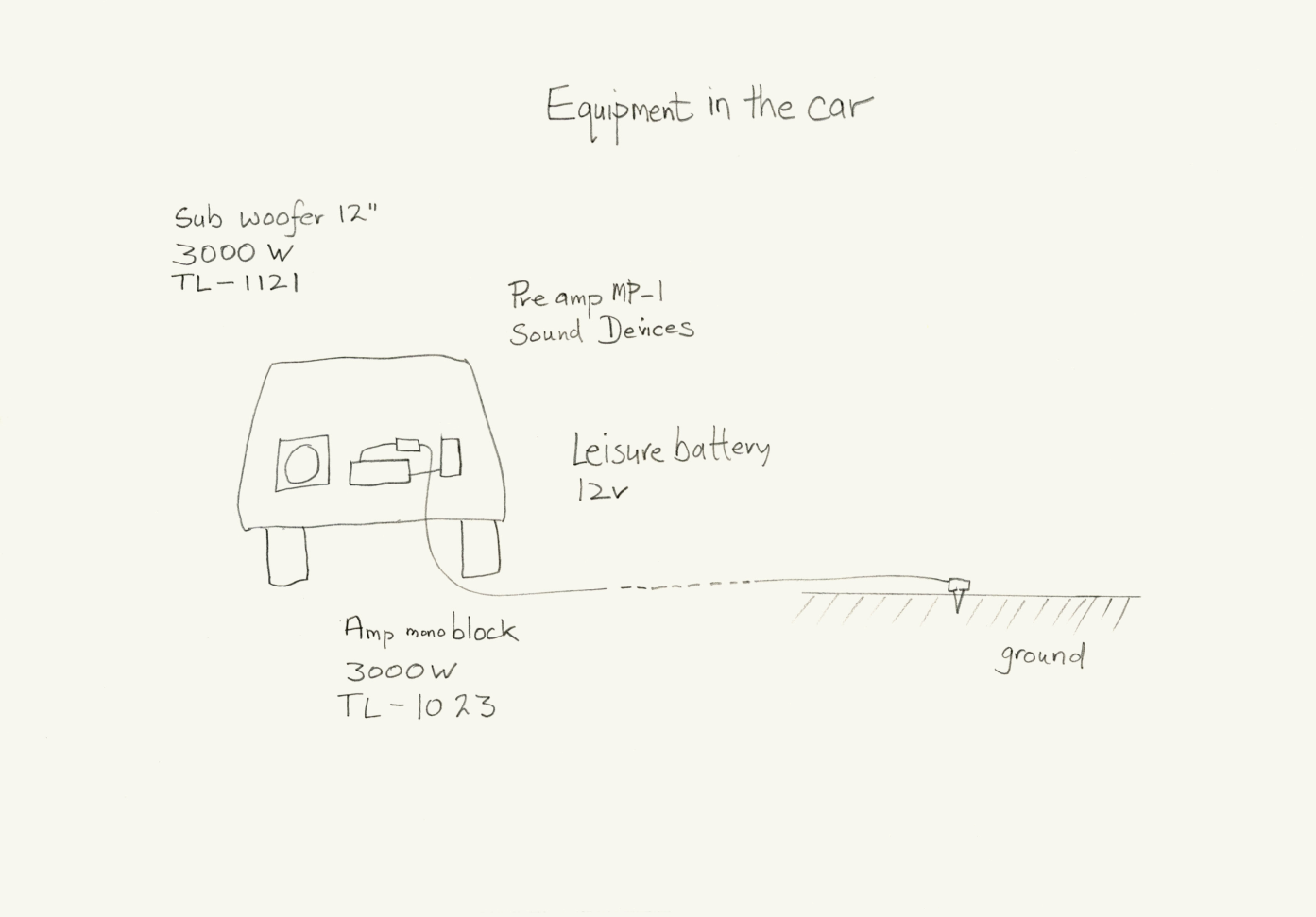


Figure 2 – Equipment in car

with what they could see through the windscreen. Whilst the means of the production of the sound heard, the cause and effect, could be understood in these cases, the arrival of the sound to the listener and the timbre of the sound were both unexpected. This was caused by both the result of the amplification of the vibrations picked up by the equipment used, and the speed of the sound travelling through the ground being different from the speed of sound travelling through the air (See relative speeds of sound p.11).

> 'It paces time differently...'
> 'Intense – don't really know what's going on.' (*Ground Sound*)

The sound in transit was conveyed through: the volumes of Oxford earth, the metal spike and magnet in the geophone, the cable conveying electrical signals, the vibrating cone in the speaker, the air between speaker and body of the visitor in the car. All of these materials influenced the quality of this unexpected sound (See figure 3).

The behavior of the visitors to the work was varied in both installations: The Festival of Desperation 2010 in Bristol (2013) and Audiograft 2011 in Oxford. Some climbed in and sat straight down in the car, some peered in through the door, some got in and immediately started to comment on or question the experience, some listened quietly and spoke about their experiences later, some said nothing at all, some remained in the car a long time staring out of the windows as if travelling, some walked near the geophone to create the sound for those in the car and some sat outside the car to see what was going on with the subsequent visitors. I felt that the work encouraged extremely varied reactions, possibly because of the familiarity of the car. For some it simply reminded them of travelling in their car.

> 'Like you are travelling but you're not – you notice everybody.'
> (*Ground Sound*)

The culture of sub-bass sound systems coupled with the bass sound heard reminded them of an out-door festival and they showed surprised to find this not 'manufactured' but 'found' sound.

> 'Brilliant – Noisy isn't it?' (*Ground Sound*)



Figure 3 – Materials

Some people thought of themselves more in relation to their physical surroundings because of the unexpected sound they heard, describing what they could see.

> 'With people clomping and the cars you feel the weight of the things on the earth.' (*Ground Sound*)

The experience posed questions as to just what was going on under the ground and if they could feel this vibration, what else was there in the kilometers below?

> 'Is there just a massive sound that is inaudible to us beneath our feet?' (*Ground Sound*)

In this last comment the visitor is tracking back along the journey of the sound they are experiencing to its source, and questioning where that source may be. As well as the sounds they hear being caused by an impact they can see, there are vibrations from the sub speaker from sources they can't see. From the advice of the Field Officer, John Laughlin, at British Geological Society (BGS) (2013), I knew that the geophone was picking up vibrations from the impact on the surface of the ground of the city's traffic and building work, as well as natural seismic signals from kilometers down and around the instrument. I also knew from my visit to HMO, that I was receiving signals inaudible to my ears from natural seismic vibrations from further afield that we couldn't hear.

In *Ground Sound* the visitors mostly became aware of the geophone as a microphone in the ground, in their view, creating the sound and vibration. The geophone design, as advised by Professor Chris Jones of the Southampton University Institute of Vibration, allows it to work with the amplifying equipment, enabling audible sound to be heard and inaudible vibrations to be felt, which would be more useful to me in this setting than the seismometer which only usually displays data on a screen (See figure 4). Geophones are used commercially in geological testing sites in series, where they collect data and describe the subterranean strata with echolocation using sound waves. The identification of a sound source requires a series of seismometers in triangulation, so with the equipment I had, I was not able to identify the source of the vibrations received (except for those described above in this text as seen through the windscreen). The questioning, however, of what was 'beneath our feet', was key to the work, and

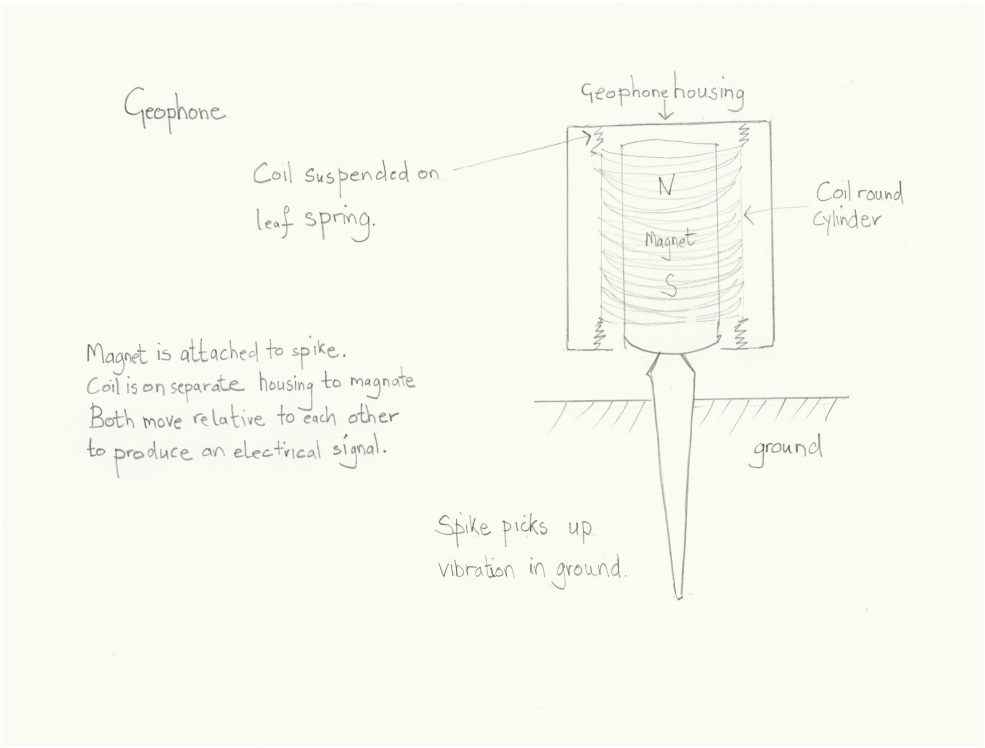


Figure 4 - Geophone

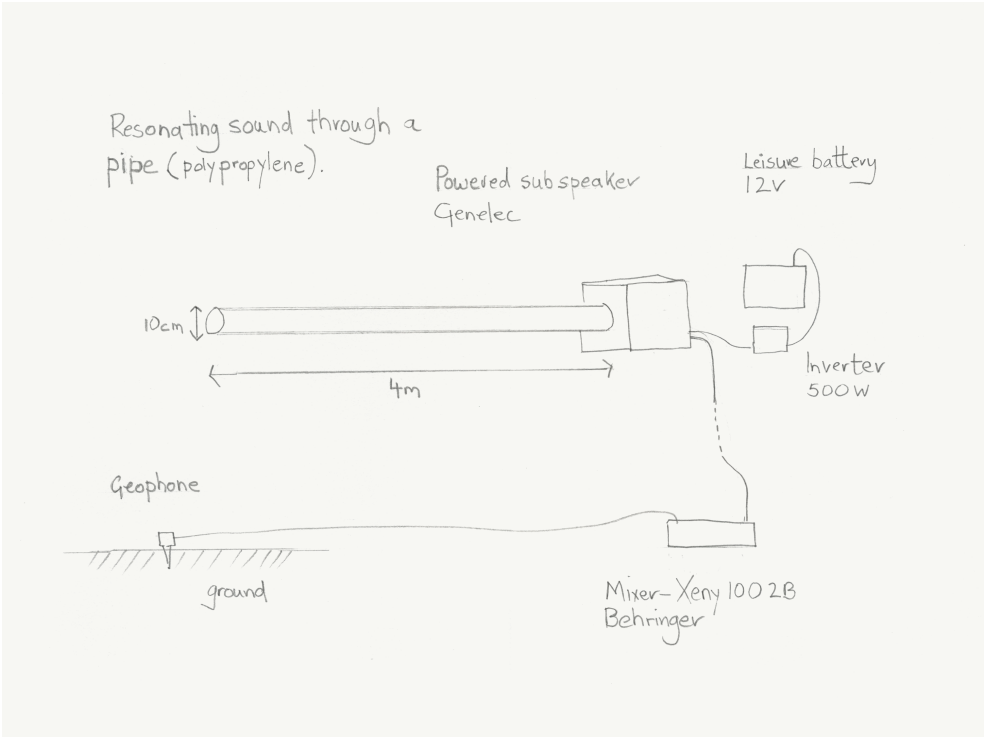


Figure 5. Pipe equipment

encouraged the idea that beneath our feet, kilometers of solid matter, was a place that we could contemplate.

Previously I had made a work where my intention had been to think of what was beneath our feet by creating a pipe long enough to channel the sounds from the ground, where the length of the pipe would illustrate the length of the sound wave (See figure 5). I was interested to show that sound waves found in the ground were extremely long, drawing attention to the properties of sound in the ground and therefore what was beneath our feet. Without providing written information about the length of the low frequency sound waves, this fact of physics was not self-evident. The experience of *Ground Sound*, on the other hand, showed the visitors projected their own different car associations when prompted by their experiences of visiting the car, sitting in it, feeling and hearing the vibration. They therefore had their own differing ideas about the work, bringing their own, sometimes contradictory, associations to their experience,

> 'Ominous and spooky - not quite comfortable,'
> 'Very comforting,'
> 'Like I'm underground- having something over the top of me,'
> (*Ground Sound*)

Mixing Senses

Contemplating the sound beneath our feet, deep in the underground, allows us to imagine the journeying of the waves through the earth; from unknown sources coming up through and going down through the ground's surface. It invites us to shrink the earth down to a sound conveying entity, an amplifier of low frequency sound and vibration, a planetary sized subwoofer. My initial aims of presenting live sounds from under ground and exploring the transit of these sounds were complemented by discovering the relationship between sound and touch: the sensation of physical impact. The following passages describe our relationship to sensation and vibration where it occurs in *Ground Sound*. Here was not only the expected rumble of low-frequency audible sound and the feel of its vibration set in a car, but a re-adjusting of our surroundings experienced via the properties of sound through the heightened sense of surfaces (See figure 6). Following the thoughts of the metaphor of the earth having a skin, it follows that the earth's skin type could be soil, rocks, pebble, marsh, sand, asphalt, mud, clay, turf or paving stones etc.



Figure 6 - Surfaces

> ‘I can see the ground as if it had surface tension and on top of which we – the pedestrians and the traffic skated like water boatmen –lightly sounding the meniscus or skin on the top of the pond’. (Artists Journal, 2010)

I take the idea of the skin of the earth further and examine and compare sound in different environments: the surface of the earth as represented by surfaces familiar to us, and the environment of the car. The idea that there is a ‘skin’ - our own skin, or the skin of a drum - that can receive or transmit sound has given me a new perspective on the sound worlds we move in.

The concept of skin as our receptor for receiving sound is an interesting one. Steven Connor from his *Book of Skin* describes skin as,

> ‘…an audiophonic aggregate, both a kind of mouth, or sounding board, and also a kind of ear.’
> (Connor, 2009 p.74)

Brandon LaBelle in his book *Acoustic Territories* (LaBelle, 2010), as a child drummer, and like Evelyn Glennie a profoundly deaf percussionist, has written about experiencing vibration through his skin and body and draws a comparison with the skin of a drum. Glennie comments in her writing *Hearing Essay* (1993) that,

> ‘Hearing is basically a specialized form of touch.’ (Glennie, 1993)

Illuminating the idea of the resonant drum or human skin, as a,

> ‘…shared border between its subject and its exterior,’
> (LaBelle, 2010 p.140)

LaBelle describes how vibration is something very elemental to each of us, a deep point of contact working with our subconscious and conscious selves from our earliest moments of growing. Didier Anzieu describes how the child in the womb experiences the sound of a mother’s voice as vibration.

> ‘The child experiences the mother as the “first skin”'
> (Anzieu in LaBelle, 2010 p.135).

My interest in low-frequency sound in the ground drew me to investigate the car and its culture of low vibrations. Sometimes, at traffic lights, a car pulls up and overpowers you with a wash of sound. Driving in my car, I know I am within the boundary of my own territory; a bubble equivalent to my front room, so someone else's sound feels an affront to my privacy. Michael Bull states in his book, *Car Cultures*, that car interiors,

> '...have an ability to create domestic comfort and security'.
> (Bull in LaBelle, 2010 p.143)

The car, interestingly, is a private and public place. The car is like a skin - a secure bubble holding a sense of privacy inside, but we know that this is an illusion because, like the mother's womb, sounds will resonate through it.

This is the first time in the study I come across the idea that the senses are not separate as we describe, but often merged. Because our language does not describe this, or there is no term for it, then we still refer to these senses as separate rather than integrated. I interviewed Gemma Smith, who is profoundly deaf, about her experiences of *Ground Sound* in terms of the vibration she felt, and if sign language had words to describe it. I asked,

> 'You described the small vibration being like the 'wind' or the 'rain'. Inuit have hundreds of words for snow. Have you any other descriptive words for vibrations? Maybe describing strong vibrations...?'

Gemma replied,

> 'Yes – we describe it easily through sign language and make the vibration visual to help describe it to other deaf and partially hearing people. It's hard to describe it in English!!'

Gemma's 'hearing' is as Glennie described, 'a specialized form of touch'.

<u>Familiarity and Imagination</u>

Setting the location for the work in a car came about initially because of the way I researched the equipment. The impetus to involve the visitors to interact with the car, for example getting into it if they wished and experiment with the geophone,

was common to my existing practice. However, the feedback from the visitors brought previously un-thought of ideas stemming from the familiarity of the settings, which invited me to think there was a correlation between known experiences and the imagination, and encouraged me to create further familiar locations for works. These examples (below) encouraged me to see the location in a new way.

> 'In this bubble - feels like you're on a stake out,'
> 'Feel like I am watching a film playing out,'
> (*Ground Sound*)

I saw that the car as a framework for the piece was more than a physical structure in which to house the equipment, but also a place where the properties of the sound and the setting brought cultural associations, this time with drama and cinema (See figure 7). LaBelle's comments indicate interesting possible interaction with a work such as *Ground Sound* where the visitor is central to the action of the ideas.

> '..windscreens provide a cinematic perspective to ultimately encase a driver within his or her own dramatic performance….' (LaBelle, 2010 p.149)



Figure 7 – Cinema

The nature of the all-pervasive vibration in *Ground Sound* reverberated through the ground, the car, the skin of the listeners, and encouraged the lifting of not only the physical boundaries but also the boundaries of the imagination. Marcus Boon describes the effect of a carefully tuned but powerful sub-bass system at Notting Hill Carnival:

> '..they were able to produce deep and powerful effects on our bodies and minds that opened up a different world...' (Boon, 2012 p.31)

From the experience of making the work *Ground Sound* and reflection from the visitors' ideas, the 'different world' of the imagination prompted me to tease out three questions in relation to my research question: *How can the physical properties of sound become manifest through the production of Sound Art works*? I wrote in my journal, 'What equipment could I use to identify and reveal inaudible and audible sound waves in the earth?' 'Can we map geographical spaces in our imagination from our understanding of sound?' and 'Can we map ideas from an inaudible sound experience or a suggested sound idea?' The work *Ground Sound* helped me to identify these questions that would inform subsequent research.

This chapter is called 'Vibration on the Skin of a Drum' to draw attention to the image of the tightened skin of a drum that might be sounded or played. It was interesting to observe the way the audience experienced the work. They did play the ground like a drum. Due to the very varied responses, it was evident that this work encouraged people to interact with it: sitting in it and getting out to try to make sounds via the geophone. We don't usually pay any attention to the experience of walking on the earth or think about our footsteps setting off vibrations through ground. In *Ground Sound* the amplification of vibrations picked up by the geophone revealed an experience of the depth and resonance of the responsive and audible solid matter under our feet.

Chapter Two – From Memory

In this Chapter, I describe the work *Through Walls* (2011). I noticed how the ideas from people who interacted with this work brought associations from their own memories, and comment on how the interaction of the visitors with the work became an element of my process that affected subsequent work in the study. The exploration of sound in a familiar home context and using a domestic setting was established in this work, and continued to influence subsequent works in the study.

My practical research 10m down in the Redcliffe Caves (2013) in Bristol (See figure 8) influenced the work when I listened to very quiet sounds through rock with a geophone. I wrote at the time,

> 'The faint sounds seemed somehow amplified and more potent in their remoteness deep down in the quiet underground.'
> (Words from journal 2011)



Figure 8 –Redcliffe Caves (Photo Rebecca Gasson)

When I heard in the caves, the disconnected sounds from overhead, it reminded me of the situation, when I was small, of being relegated to my bed, hearing my siblings downstairs. Although at that time, the sound did not just resonate through the floorboards, the experience of its quietness spoke of my separation from all the fun going on in other parts of the house. I started to think about how spaces are described by sound and how therefore a sound can describe the spaces that are separated from the listener.

The journey of the sound, in my childhood house, filtering to my ears upstairs must have come via several routes, although I probably was not thinking of that at the time. I imagine the house would have sound travelling along the corridors, up along the banisters, vibrating through footsteps onto floorboards and resonating along the joists of the structure, from vocal chords of speakers up into the air - dampened by curtains and carpets, loud sounds vibrating from floorboards into the shoes of walkers and the bones of their wearers. Brandon LaBelle describes a work of Toshiya Tsunoda *Monitor Unit for Solid Vibration*, where the focus is entirely of the sound travelling through the wall,

> '…walls are not strictly surfaces defining space through material and visual perspective, but they in turn, contain a plethora of acoustical events…' (LaBelle, 2008 p.239)

The artwork *Through Walls* focuses on one sound track, again heard entirely through a wall. Containing a 'plethora of acoustic events', it is the wall that gives the visitor an experience of the journeying or route of sound to the ear.

Through Walls was located in a room where sound was diffused through the fabric of the walls, in this case plasterboard and brick, from outside the room via eight small speakers (VISATON FRS 7.4 Ohm speakers) attached to the wall (See figure 9). This recorded sound, playing on a loop, was inaudible from inside the room till you pressed your ear to the wall. The recording, playing on a CD player was connected to a 60W amplifier (Denon UDRA-M7) and to the eight speakers connected in series (See figure 10). In the centre of the room was a table with an assortment of tubes, stethoscopes, glasses and funnels placed on it, that could be used to extend the ear in listening to the sound in the walls or in the windowpanes (See figure 11).

The looped recording was of everyday sounds of my house. A composition of domestic noises consisting of footsteps on the stairs, the vacuum cleaner, radio, doors slamming and dogs barking. They were chosen from those I heard around my own house as sounds that might be common to other households and recognized as such. By experimenting with the implements, the visitors could find out the difference that each implement made to the hearing of this recording. The sound travelling through these implements attached to their ears would change the sound heard through the surfaces; sometimes amplifying it and sometimes making it softer.

In the work *Through You* I hoped that the active listener, like a cold war spy listening into the next room, would engage with the separation of the sound source to them, trying their best to hear the secrets revealed next door. The experience of the sound was altered by the separating materials, the structure of plasterboard, timber and brick and the different acoustic properties of the instruments they used to listen with. This dampened sound would create the idea that the sound source was from another place: the other side of the wall or somewhere else in the house.

An aim of the work was to focus awareness on structure-borne sound in the room rather than being an appreciation of the sounds themselves. I make the distinction here regarding my study and the genres of sound art and refer to this as sound that is listened to with reference to its source. Seth Kim Cohen outlines the different way Pierre Schaffer defines sounds, where he:

> '….isolated what he referred to as the objet sonore, the sonic object. He suggested we should listen "acousmatically" without regard to the source of the sound.'
> (Kim-Cohen, 2009 p.xvi).



Figure 9 – Speakers

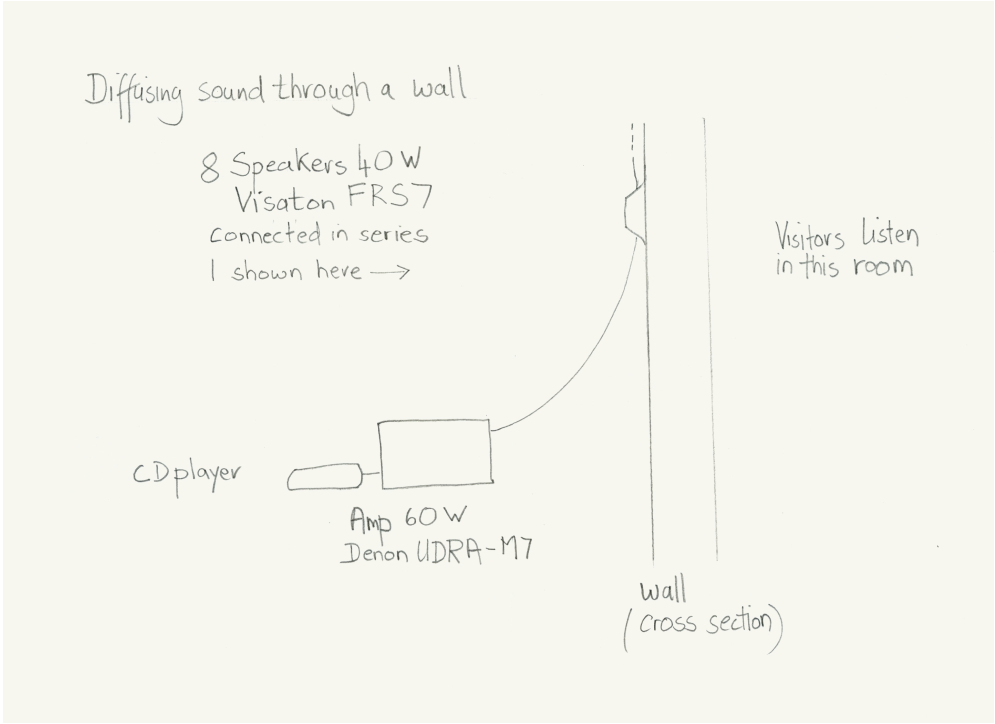


Figure 10 – Wall equipment

Thinking of the source of the sound is an important idea in the work *Through You*. Attention is drawn to the means by which the visitors are creating the variation of the sounds by testing different implements rather than the 'appreciation' of the sounds themselves. Listening to the variation of sounds via the different instruments encouraged the visitors to compare the sounds they heard in the setting they heard them. This in turn required the visitors to think of the journey of the sound to their ears, sometimes along tubes and glasses, through the wall, and from source to its perception. Understanding that there was a reason for the sounds to be present other than to be listened to for its own sake, came about because the listener was required to actively create ways to hear them, testing different implements to explore the different possible sounds for themselves (See figure 12).



Figure 12 - Listening

The idea of structure-borne sound is shown in the work of Maryanne Amacher and is described here by Brandon LaBelle:



Figure 11 - Implements

> ‘Locating sound in a-joining rooms, along a hallway, sounds occur structure borne, travelling through walls, floors corridors and ceilings. ...Utilising such sonic behaviours space can be incorporated into the sculpting of particular sound work: rather than house a work, work can literally become a house.’
>
> (LaBelle, 2008 pp.172 -173)

In the work *Through Walls*, I specifically wanted to bring about the activity of listening through the fabric of the wall rather than engage with the effect of the resonating of the house or building’s corridors, as described by LaBelle. LaBelle’s thoughts do however liberate the idea of how a sound could be heard; no longer confined to being heard through a speaker but vibrating through the walls of a house. Here is a quiet echo of the vibration resonating through the fabric of houses as created in the work of Mark Bain, where in his work *Trembling Structures* (Bosma, 1999), the walls were shaking with vibration.

This liberating idea helped create another work for this study, although not discussed in this commentary, where a recorded sound was resonated via a transducer, through the wood of a set of chairs, and the chairs themselves became speakers (See figure 13). *Ghost Quartet* (2012) was a collaborative work with sound artist Wajid Yasseen (2013) and commissioned for Audiograft 2012. The four chairs in a row, although set in a gallery, like the wall in *Through Walls*, suggest common associations with settings such as: a doctor's waiting room, a panel of judges, or a string quartet. The work *Ghost Quartet* responded to the idea that a familiar object that we would not think of as a sound amplifier could amplify sound, and conveyed the simplicity of the notion that even the furniture around us and the wood of trees can convey sound to us.

In *Through Walls* visitors chose sound listening objects that extended the capabilities of their own ears, and their individual creativity at making ever more inventive ear extensions made an impression on me. I started to think of the ear with its evolved shape, and the internal pathways and connections that allow us to register sound in our brains. I became interested in the processes of the ear itself, which led to works titled *Through the Bath Water* and *Through You*, described in Chapter Three and Chapter Four respectively.

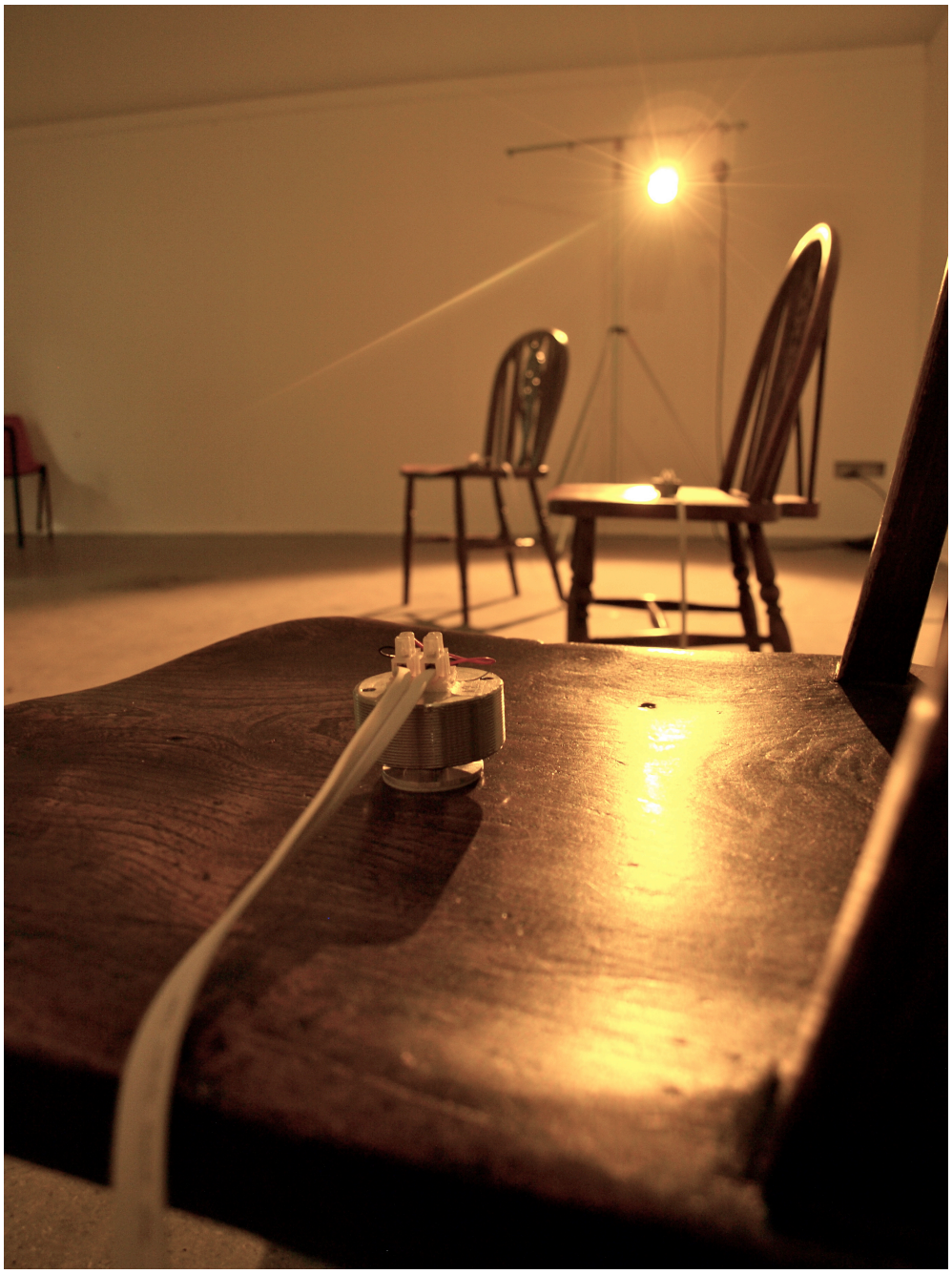


Figure 13 - *Ghost Quartet* (Photo Sarah Hughes)

I saw that the visitors were thinking about their hearing: and the function of their own ears. Their enjoyment of exploration was fedback to me. The physical engagement with the processes of the work invited individual visitors to form their own ideas. In the room, quiet listening took place as well as discussion between visitors about their experiences, laughter at their choices of implements and the exchange of ideas to create different ear extensions. I became interested, too, in the interactive ideas and actions of those that came into the room. I realized that it was possible to develop a process to include the interaction of people stimulated by the ideas of the artwork. It opened up possibilities for my process in this research which, up till now, I had not considered including to this extent.

When I visited the *The River Runs* project at Modern Art Oxford (Urbonas, Warr and Castagnola, 2012) initiated by Urbonas Studio in collaboration with artist and writer Tracey Warr, I was interested that their process in a series of works included the interaction of people who were concerned with the active collecting, and generating of ideas. In one of their works, *Ruta Remake* (2002/4), Nomeda and Gediminas Urbonas describe their methodology whereby the ideas are communicated in a variety of different ways:

> 'The work as a whole investigates new modalities of production. Through group work, it intervenes in different areas of communication, and utilises as (sic) networking methodology that generates different strata, each of which adds new meanings, associations and experiences.'
> (Urbonas, 2008 p.33)

In *Through Walls* the actions of the visitors testing out the implements, communicated ideas to those who were just arriving, as to what they might do. The implements laid out on the table also acted as a visual clue. A few visitors collaborated on making multiple ear extensions where their communication was verbal and gestural. Within the room I saw how the enthusiasm for exploration was infectious, and different ways of communicating were created in order for it to take place.

The idea that the interaction itself could be the artwork opened up opportunities to explore further work, where the status of the visitor could be that of communicator and collaborator as well as observer. Sound artist Wajid

Yaseen.(2013) and I set up the event *Work in Progress* (2012) at the Soundfjord Gallery, London (2012). In this interactive event, Yaseen and I, along with the visitors who attended the event, explored items of equipment that would play sounds not only into walls but also any object; including the human body. This approach was suggested by David Tudor's *Rainforest* piece where he used a collection of eye-catching and familiar objects to resonate sound (Southerland, 1999). This work in turn helped developed ideas for the work experiencing sound through the body called *Through You,* described in Chapter Four.

In the artwork *Through Walls*, the focus on the hearing of the sounds through the wall brought engagement with the means of hearing, the making of the ear extensions, the exploration of sound and being reminded of past experiences of hearing sound through walls and windows. These aspects of the work went towards answering the question, *How can the physical properties of sound become manifest through the production of Sound Art works?* The physical properties of sound in this case were both: real, where the sounds were diffused through the wall; and imagined, where the sounds caused the remembering of experiences.

The emphasis of the work*,* rather than hearing sounds from a specific location, was that the location, in this case the wall, would represent a 'generic' wall, like one from the visitor's own house. This would shift the emphasis of the work from concern with location, the wall and the ear extending tools, to that of the perception of the visitor. A key to the artwork discussed in the chapter, is the idea that the familiar sound track of the house in *Through Walls* would encourage the visitors to think of their own homes that would be rich in association for them. They were in effect mapping out ideas from the experience of their own homes from a suggested sound idea, the track coming to them from the wall. These experiences would allow the visitors to not only bring themselves, but their memories of sounds filtering through to them in their own houses, voices from their cultural backgrounds issuing family communications, noises familiar to their daily lives and all manner of associations to the experience of the work.

Chapter Three – Electrical Places of Water and Bone

In this chapter, I describe the work *Through the Bath Water*, investigating the contrast between hearing sound as it travels through air and hearing sound as it travels through water. After the experience of making *Through Walls*, described in Chapter Two, where the visitors were encouraged to interact with the work because they were familiar with the domestic setting, I developed work with a familiar domestic setting again, this time the bathroom. I look at the mechanical reception of sound via the ears, both in air and water in the bathroom, and explore the bathroom itself as a place where we experience sound-worlds. My own attempts at understanding my ears under water have led to much immersion in water, and consequently in this chapter I have also investigated how the ears of fish work in comparison to my own.

Through the Bath Water is an installation where the visitors to a public event at BEAM Festival (2012) held at Brunel University were invited to get into an empty bath and listen through headphones to a recording of the sound of the taps running water into the bath. Through the headphones they could hear either the sound of the water running recorded from under the water, or the water running as if you were standing in the bathroom (See figure 14).

If the person, in the bath with headphones on, reclined back tilting their head so the headphone was at an angle, it would affect the sound they were hearing. This angle would tilt an Arduino, a single board micro controller fixed onto the headphones, (see figure 15) which would trigger a Max Patch on a laptop (See figure 16), to play the sound file: a hydrophone recording from underwater in the bath. If they then sat up so the headphones changed position, putting the Arduino at another angle, it would then trigger the Max Patch to play the second recording, recorded from above the water. Listening to the underwater or out of water sounds of the bathroom, i.e. lying back or sitting up, corresponded to physically being under or over of the bath water. These two looped sound files were accessed from a laptop placed under the taps end of the bath, and from there a cable ran to the headphones placed at the other end of the bath.



Figure 14 - Reclining



Figure 15 - Arduino

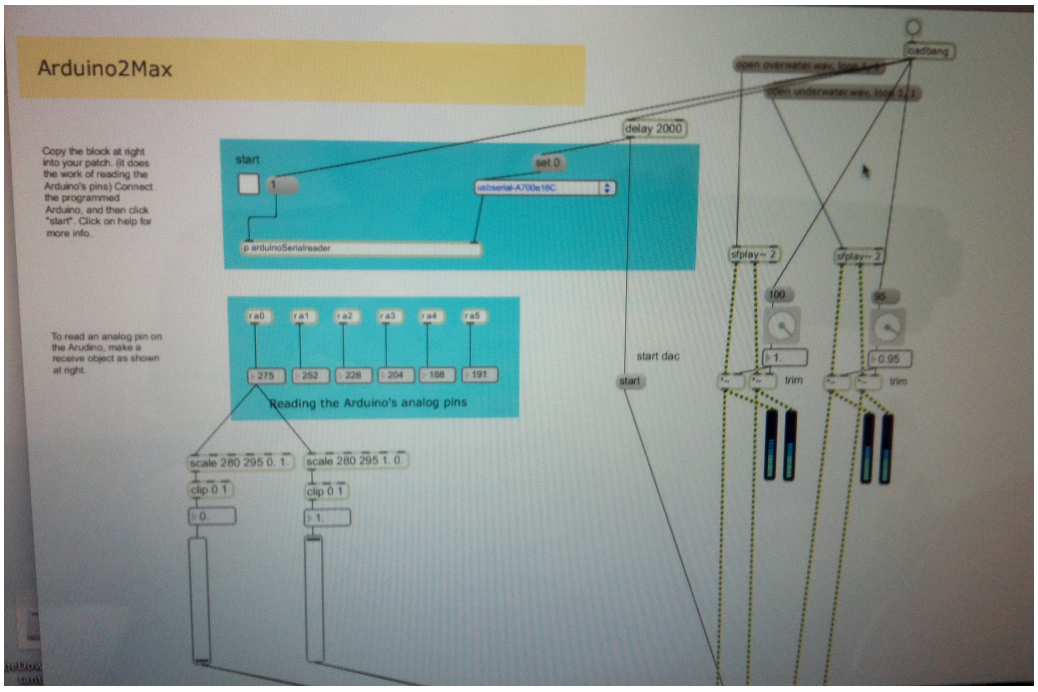


Figure 16 - Max patch

When I recorded sounds for *Through the Bath Water* in the bathroom, I had to make decisions about what I would include on the recording. I didn't want to distract the audience from the sounds I wanted them to hear. I chose therefore to concentrate the listeners' attention on the comparison between the sounds of the tap water running as heard in the air and as heard through the water as this would focus their listening on their experience of sounds changing as it travelled through these two different materials.

To make the recordings of the sound in the bathroom, I set up two AKG 200 microphones for the air-conducted sound and a hydrophone (Aquaphone H2a) for water-conducted sounds (See figure 17). Both recordings ran simultaneously into an Edirol R- 44: a multi-track digital audio recorder. I experimented, when listening to the hydrophone picking up the underwater sounds, with: putting the radio on in the bathroom; having people come in and speak; recording noise outside the window; and, humming in the room loudly and then softly. I found that as soon as there was some different element to follow than the bath water, there became a narrative to listen to - the narrative of what was happening in the room. This narrative then overrode the focus of the sound itself and its behavior, so I recorded only the bath water. I also considered, but eventually rejected, other bathtub sensations, of this sound idea, such as simulating hot water by heating the side of the bath. I hoped the sonic differences would be clear enough to allow them to compare and contrast the frequencies heard and prompt them to recall their experiences remembered from their own bathtimes.

<u>The Bath Room</u>

I will describe how visitors encountered the artwork, and how the cultural context for the work played a part in their experiences at Beam Festival 2012, where the work was shown. The bath was set in a corridor rather than in a gallery or indeed a bathroom. The locating of the bath in the corridor where it seemed 'out of place', brought up the issue of the visitors' privacy, for whom getting into a bath, normally a private activity, was now a very public one. There were comments such as:

> 'Would a shower curtain change the experience?'
> 'Thought I might feel naked in the bath!'
> 'Didn't like staying in being watched.' (*Through the Bathwater)*

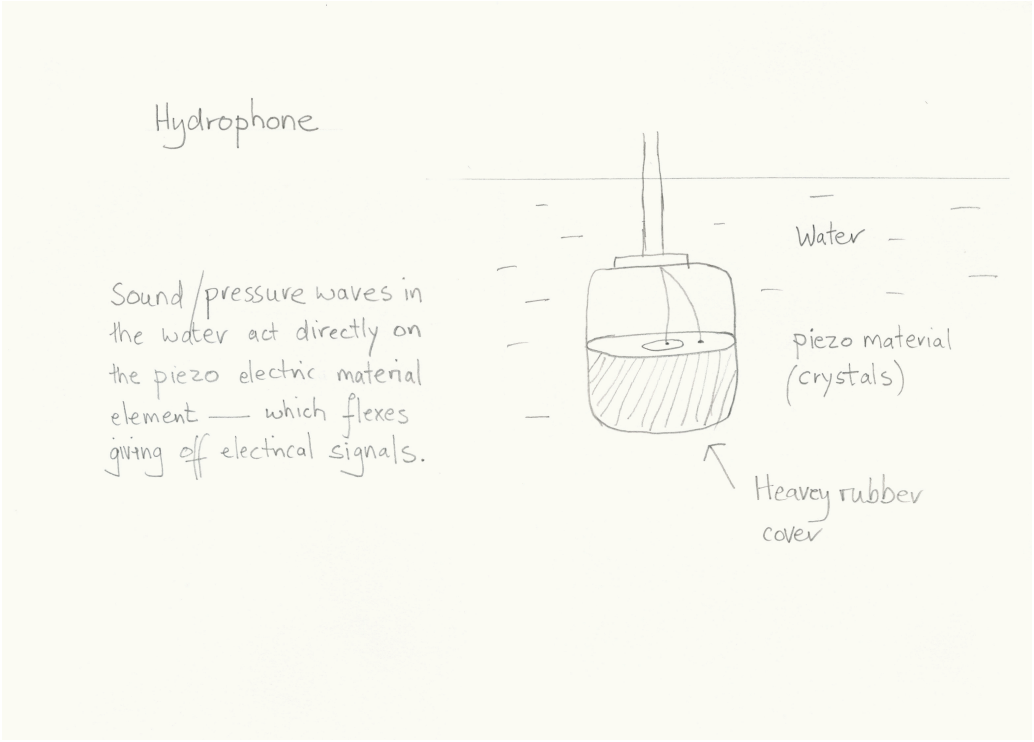


Figure 17 - Hydrophone

Presenting the artwork in a playful way and encouraging the visitors to try a different experience if they dare, did seem to bring about a more memorable experience for the participants. As part of this study and in my on going practice I was interested in habits associated with a familiar location. Here, a bathroom, where privacy is usual, would influence the actions of visitors even if the location was just the suggestion of a bathroom in a corridor. To invite the visitors, however, to try the experience of the bath and as the sounds I created were on headphones and could not be heard out loud, it was necessary to show visitors how they could hear the sounds. To imply that visitors could get into the bath and put on the headphones, rather than instruct them to do so, I left a photograph of a person in the bath and words on the bathmat that read: 'Shoes Off' (See figure18). Different reactions from the participants indicated that this required them to make a further effort to participate with the artwork i.e.

'Taking my shoes off made me slow down' (*Through The Bathwater* 2012)

I questioned how much the visitors' interaction with the work, for example 'slowing down' in the way they might do in their own bathroom, prompted them to relive a bathroom experience.

There are two main reasons why I chose to work with the idea of a bathroom. Firstly, it is a private and very familiar place we occupy a lot, mostly on our own and possibly with time to contemplate. Although we don't probably take much notice of our daily visits, our knowledge of them is detailed for every sense: to hear, touch, taste and smell. Secondly, the acoustics are usually memorably resonant because of the shiny surfaces where sound can be reflected and loud sounds, noticeably voices, are amplified. I remember as a small child hearing a singer loudly bursting forth into song in the tiled and resonant bathroom, and being astounded at the volume of noise from behind the door. Georges Perec describes rooms of an imaginary apartment by function, and for me what he calls the 'auditory' I imagine as the bathroom.



Figure 18 - Bathmat instructions

> ‘It takes a little more imagination to imagine a room no doubt to picture an apartment whose layout was based on the functioning of the senses. We can imagine well enough what a gustatorium might be, or an auditory, but one might wonder what a seerry might look like, or a smellery or a feelery.’ (Perec, 1974 p.31)

Key to my study is the revealing of previously un-discovered of ways of perceiving a well known place in our daily lives, like Perec’s description of his apartment. The combination of this specially unnoticed room and the physics of its acoustics I found was a good preparation for locating a work in a room that would impact on our imagination.

The Human Ear

In *Through the Bath Water*, I used the underwater recordings from the hydrophone, but in the process of making the work I continually investigated how my own ears worked underwater. In the following examples, I am concerned with explanations of the human ears’ mechanisms in reacting to sound travelling through the different material properties of water and air. The source of these under water sounds is the water running into the bath from the taps and the ‘clinking’ of the metal plug chain (See figure 19). The source of the sound from under the water to my ears (underwater) travelled differently, seemingly filtering out some sound frequencies and accentuating others.

I learned while listening that although water is approximately eight hundred times denser than air and capable of conveying sound approximately five times faster than air, it did not seem to convey sound more efficiently to me via my submerged ears (Horrowitz, 2012 pp.49, 50). The density of the water did change the sonic properties reaching my ears, however the transit of the sound through different parts of the ear also affected the sound.

In the human ear, the ear canal leading to the ear drum, is not designed to be full of water as it is when your head is underwater. The ear has evolved to convey sound from air to the middle ear, and water in the ear canal upsets the system (Horrowitz, 2012 p.49) (See figure 21). Higher and lower rather than mid frequencies are heard more easily in water, whilst listening submerged, because the ear picks up the



Figure 19 - Underwater

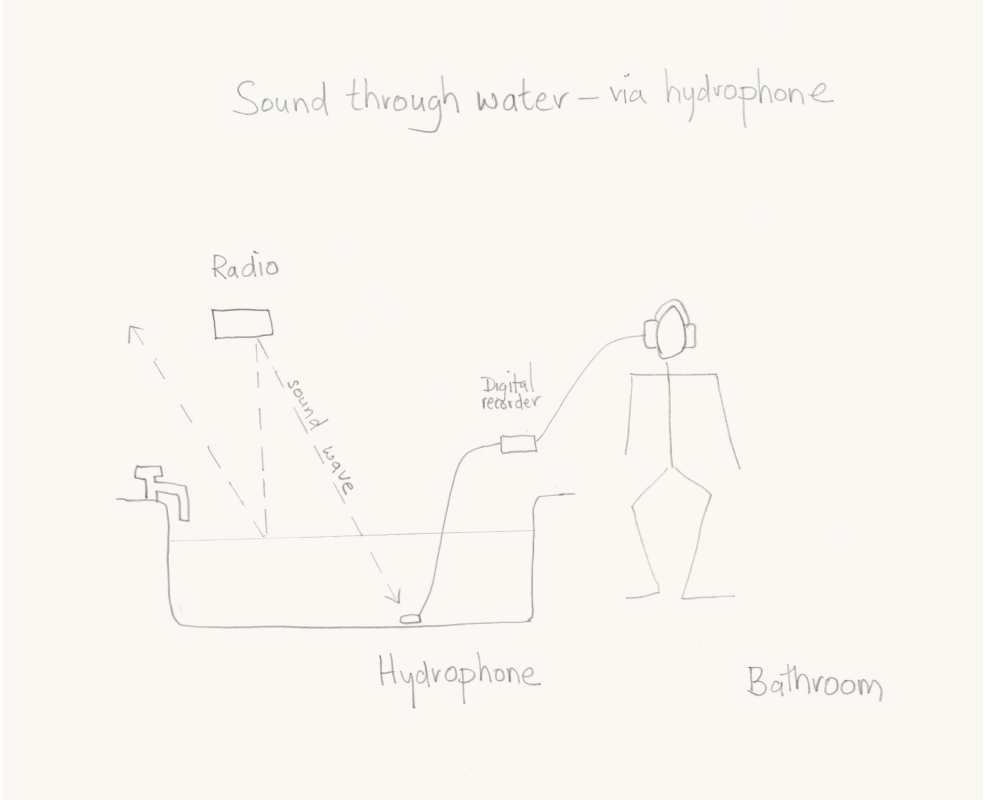


Figure 20 – Sound via hydrophone

extreme frequencies more efficiently hence the mid-range sounds are more indistinct. (Library.thinkquest.org.n.d.)

Sound travelling through water to the ear affected not only the timbre of the sound but the mapping of the journey to the ear. The divers manual advises that direction of the source of an underwater sound when listening submerged is often obscured. Although it was easy for me to identify in the small bathroom, it would be harder to guess where sounds come from in a larger environment and would involve me listening to the direction of the sound via the speed it reached either my left or right ear (Library.thinkquest.org.n.d.).

The enclosed feeling of the water engulfing my head and ears was redoubled by the heightening awareness of the sounds coming to my ears from inside my head, due to the sound being conducted through the bones as well as the body tissue (Library.thinkquest.org.n.d.).

Tracking the sounds' course through the water and through the mechanical apparatus of the human ear illustrated sonically, because of these mechanics, the ears' efficiencies and inefficiencies. The combination of elements involved in the journey of the sound waves from under the water in my bath and culminating in the firing of impulses from the ears' cochlea via the neural canal to the brain (See figure 21), inspired this chapters' title Electrical Places of Water and Bone.

The Hydrophone

My own experiences of immersion in water helped clarify my bathtime memories of being underwater, but as I was unable to ask the visitors to immerse their heads in water I needed to use a hydrophone as my 'underwater ear' to give them the experience of hearing sound underwater. This extension of our human ear, a prosthetic or bionic version of our not so effective ear, was more efficient. The hydrophone, because of the peizo material it uses (See figure 17), has a more similar acoustic impedance to water than it does to air and therefore is more effectively used in water than air (Au and Hastings, 2008 p.28).

I comment first on what I heard with the hydrophone picking up sounds from under the bathwater and comparing this sound with what I heard just standing in the room (See figure 20). To make this comparison I used a radio in the room as the

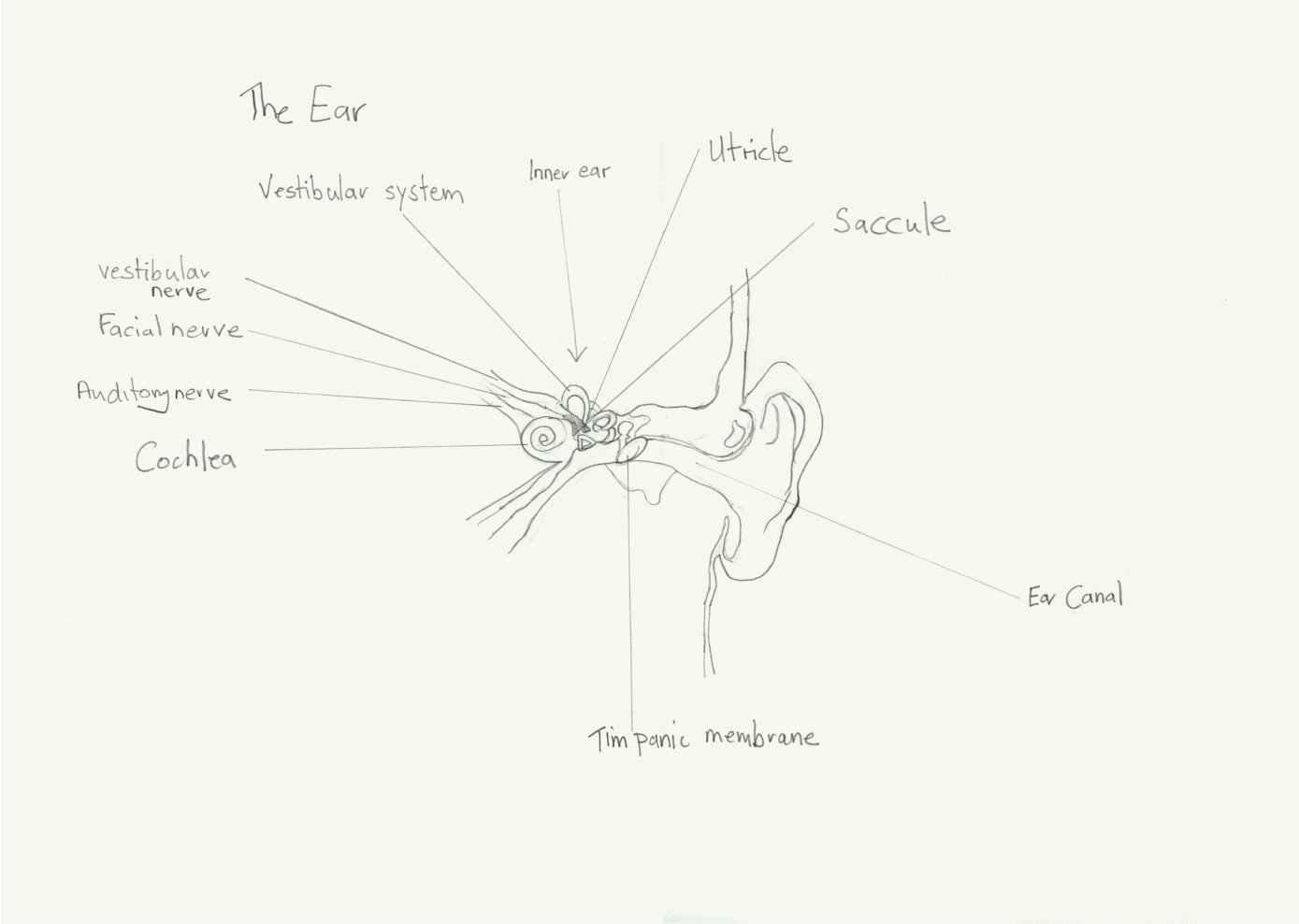


Figure 21 – Ear

sound-source to enable me to listen to distinct sounds. The sounds I heard from under the water seemed more 'compressed' or removed from the same sounds heard travelling though the air.

I learned that when listening with the hydrophone:

- sound travels faster through water than it does air, because of water's elasticity and density. (Principles of Underwater Sound Sea, 8.4, 8.4.1)

- Sound travels approximately 1482 m/s in water as opposed to 343m/s in air – depending on the quality of both. (See Chapter One)

The sound therefore of the radio playing in the bathroom, picked up by the hydrophone under the water and heard on headphones, was altered from the way I could hear it through the air in the bathroom. Sound waves change speed when they pass from air to water, and some sound waves are reflected off the surface of water and don't travel through it (Erbe, 2011 p.26).

When listening to the 'clinking' of the plug chain underwater, where the sound travelled up through the water and through the air to my ears, I found this was less distinct in the confines of the small bathroom, but I learned that some sound waves do not travel from under to over the water (Erbe, 2011 p.26) (See figure 19).

In each of these bathroom experiments with the ear underwater and the hydrophone, the experience of the sound heard is changed by the material through which it travels. Becoming aware of the speed of the sound, the reflective qualities and densities of materials leads the observer to map the route and progress of the sounds through and over water. In the art work the comparisons are reduced to the hydrophone's recorded relaying of underwater tap sounds with the recorded bathroom tap sounds in the air. In this way the differences between the two sonic behaviors could be perceived.

Alternative listeners and their experiences

One participant said of the experience of the work *Through the Bath Water* that,

> 'It gives the experience of being a fish as you can still breathe under water.' (*Through The Bathwater*)

I recalled the experiences I had had when I made the work and wondered how similar my experiences were compared with those of a fish, given that one of the drawbacks of not being a fish and listening under water is that your breath runs out and you have to stop to come up for air. This was the case when I listened to sound played through water in *Wet Sounds* by Joel Cahen (2013). I was surprised however, when the equipment, i.e. the vibrating cone in the water, diffused very clearly music and singing sounds that I was not used to hearing underwater. I surmised that this specifically designed equipment was enabling me to have an unusual listening experience, but it led me to question just what I was capable of hearing in water with my human ears. I found I was curious to know how sound could be heard in water and how creatures living in water could hear and sense sound and vibration. As a human diver, I have to learn how to listen differently when I put my head under the water. Here are the things I learned about fish pertinent to the study.

Our ears evolved from primitive fish (Fay and Popper, 1980) where the organs they heard sound with, the seccule and the utricle, have evolved in our ears as part of our vestibular system which facilitates our ability to balance.
(Berg and Stork, 1995 p.147) (See figure 21).

The hearing organ of these fish is a different density from the density of their bodies - enabling their brains to identify an incoming sound wave. Dick Fay of Loyola University describes it thus:

> 'In terrestrial vertebrates the animal holds still and the sound shakes the ear. In fish, the ear holds still and the sound shakes the fish'
> (Horrowitz, 2012 p.51).

The vibrating fluids in their bodies, the further evolution of the swim bladder and the density of the water, allows some fish to sense different frequencies from human ears.

> 'Some fish can hear up in to the ultrasonic range.' (Horrowitz, 2012 p.51)

The ear mechanisms of the fish with a density similar to water have evolved to register sound waves in water. Becoming aware of the different systems that creatures, including humans, could sense sound with, i.e. through tissue, bone and

cartilage, reinforced for me, the idea that sound waves could be sensed through the whole body.

Through the Bath Water gives experiences of the underwater world we can't inhabit. It implies or encourages you to think that there are creatures that can live in worlds we can't.

> '…gives the experience of being a fish'.

Learning about what and how fish sense and hear that is different from us, implies there are limitations to our own ears. Once we know of a sound world that our ears lack the mechanism to hear, it opens up the possibility that there is a multitude of other worlds to imagine that can be heard – if not by us, then by other species. At both ends of the inaudible scale for human ears, creatures communicate: the Blind Ganges Dolphin up to 200kHz and the Blue Whale down to 10Hz. (Krause, 2012 p.22). Our hearing is generally between 20Hz and 20kHz and higher for people under 25 (Krause, 2012 p.22). The idea that there are identifiable soundscapes that we can't access, but can scientifically verify exist, allows us to create a rich field of 'yet to be imagined' places or 'possible sonic worlds', an idea written about by artist and writer Dr Salome Voegelin.

> ' Listening offers another point of view, an alternative perspective on how things are, producing new ideas on how they could be and how we could live in a sonic possible world, and how we could include sound's invisible formlessness in a current realization and valuation of what we understand to be the actual world.' (Voegelin, 2012 p.10)

Voegelin speculates that sounds' offering of 'another point of view', another way of understanding our surroundings, is the vehicle for our imagination. For the work in this study the combination of sounds' 'invisible formlessness', works in conjunction with the familiar location of the works, the bathroom, the car etc., building on the visitors' own associations and ability or willingness to imagine.
Recent research by Dr Neil Todd at Manchester University has shown that in our evolved human ears, the seccule and utricle, retain the ability to sense much lower frequency sound than was thought in the past (Todd, 2009), reminding us that being creatures that evolved from amphibians, we share biology relating to air and water: the materials of our habitat. In our own bathrooms, hearing with our ears in

the water compared with in the air allows us to experience a ‘water world’ where the sounds we are used to in air are different in the water. Even though there is not a strict boundary between these two worlds, we can imagine we are in the ‘water world’ when listening to water running into the bath with our head submerged.

In the artwork *Through the Bathwater*, feedback from a visitor linked the sounds heard in the headphones and the heightened awareness of the sounds coming to his ears from inside his head with the physical environment of being curled up inside the bath - at this time placed in the corridor at the festival,

> ‘I like the encapsulation – physically inside the bath and physically inside the headphones. The environment was framed by the bath. It felt further closed up when listening to the underwater sound.’ (*Through the Bathwater*)

Through the Bath Water addresses the questions: *How does our experience of sound change in relation to the materials through which it is transmitted?* and *How do listeners develop an understanding of the transit of sound from source to perception?* The different properties of the water and air through which sound waves passed became evident through the investigation: the transit of sound in stages through the hydrophone, the human ear and the different sensing systems of fish. An understanding of the journey of these sounds created an understanding of their transit and the different experience gained from these journeys. In response to the question, *How can the physical properties of sound become manifest through the production of Sound Art works*? The visitors' own memories and associations of being in their bathroom, brought a sense of the different worlds the soundscape can bring into focus. Listening closely over and under water with my own ears emphasized for me the human ear's limitations (as opposed to those of fish), where I could understand the bigger picture of available sounds in the environment extending out of our human ear's hearing range and expanding my own imagination to contemplate the possibilities of infinite sound worlds and the marking out of our ‘hearing world’.

Chapter Four – I Can Feel It In My Bones

In this chapter I describe the artwork *Through You* where the investigations and thought processes address ideas concerning perception of both actual and imagined sound. *Through You*, an interactive artwork that happened between November 2011 and June 2012, developed from work started at the Soundfjord Gallery with sound artist Wajid Yaseen where we experimented with playing sounds into objects.

At each of the several showings of the work, I set out equipment with a sign saying *Through You*, inviting the public to come and try the equipment. Although not immediately self-explanatory, I hoped this title would give some context to the activity they might explore with the equipment. I developed a mobile sound kit in a shoulder bag with sound artist Matt Davies that vibrated sound into objects (See figure 22). An MP3 player connected to a small amp (Kemo 40W) and battery (SLA 12v) played sound into a transducer (surface transducer – large, 1W) used for resonating the sound from its surface (See figure 23). For the work *Though You* the sound (a recorded voice) is played into the human body, and the transducer's flat metal vibrating white surface is the contact point with the skin of the listener.

Visitors to the work were offered the portable kits and encouraged to walk around and hold the transducers against objects connecting their surfaces. The sound playing in the MP3 vibrated the transducer, which in effect was a speaker with a solid surface instead of a flexible cone, which then vibrated the surface of the object. The vibrating object became an extension of the transducer, and so amplified the sound from the MP3 player. In most cases the inaudible sound vibrating in the transducer (i.e if you just held the transducer in the air you couldn't hear the sound) was made audible by the new amplifying object, so the visitor could then compare the sound made from each object. Different objects made different sounds as the denser the material of the object the more the vibration would be amplified. This showed audibly how sound changes in relation to the materials through which it is transmitted.



Figure 22 - Listening kit

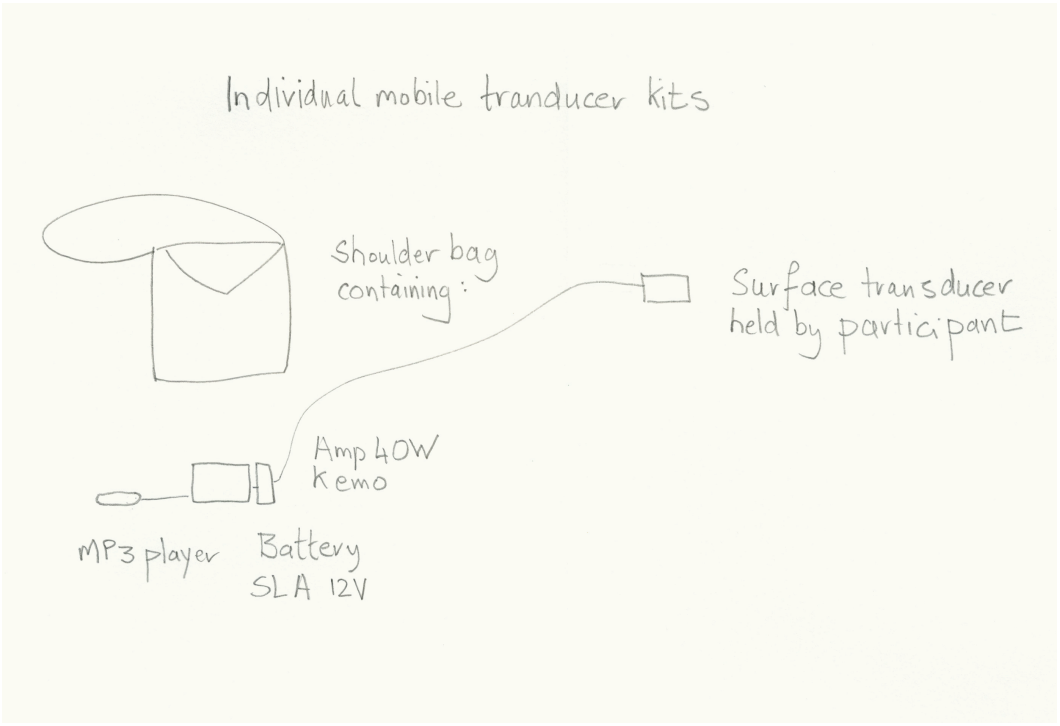


Figure 23 – Kit diagram



Figure 24 - Sound conduction 1

In the initial tryout, firstly, the objects available to the visitors for investigation included: the fabric of the room itself; floor, windows, radiators etc.; and their own and other peoples' bodies. The body proved to be the most favoured choice. Secondly, I experimented with several sounds in the MP3 players for the visitors to try in their investigations. I chose, for *Through You,* to use recordings of a human speaking voice, rather than the other recordings, because the voice is an easily identifiable sound and therefore the listener could more readily compare how it sounded when heard through different parts of the body (See figure 24). The voice on the recording describes how fast sound travels through various materials reciting a comprehensive list to give the impression that sound does travel through all materials. The listener could hear the voice whilst simultaneously testing it through parts of his or her own body.

David Wogen at the Faculty of Environment and Technology, University West of England, advised me about the equipment to ensure that the voltage being put in close proximity to any part of the body was at a safe level.

> 'People with pacemakers should keep the device well away from their pacemaker as frequencies between 1Hz -1kHz can affect them. They can also be disturbed by magnetic fields greater than 10 gauss.
>
> There is a risk in some people of inducing epileptic fits with certain noise patterns and you can cause tissue damage with frequencies below 100Hz but only at high decibel levels(>100db).
>
> Overall I don't think there will be any risks to the average person as the level of sound reaching the body will be reduced due to the impedance mismatch between the air and your body tissue.'
> (Excerpt of correspondence 2012)

Putting the transducer on different parts of the body meant that the materials in their bodies were vibrating and the vibration was being conducted to their ears from inside their bodies, mostly via their bones and fluids (See figure 21). Visitors listened through their bodies; discovering the different densities of various parts of their bodies through experiencing the different sound they produced. Here the experience of sound changed in relation to the materials through which it was

transmitted. The elbow proved a very good conducting point to conduct sound (See figure 25), whereas from the knee the sound heard was much quieter. Gauging where the sound was travelling up through the body provided the listener with a map of the sounds' transit to the inside of the ear.



Figure 25 - Sound conduction 2

Describing the unusual idea of listening to sounds from within the body, I will mention two outcomes pertinent to the questions of the research. Firstly, the experience of *Through You* caused me to think objectively that I am an organism of skin, bone and fluid, capable of conducting sound; putting 'me' in the same category as the other materials I have been considering in this study. This idea suggested by the transit of sound through our bodies, allows us to experience the external travelling of sound, right through us from its source. Noticing this internal sound, where sound waves conducted by bones and tissues are heard from the inside of our ears, can highlight the way the experience of vibration across the planet can effect us, via our bodies. Secondly, another observation of this internal listening, this time to the listener's own voice, is commented on by Douglas Kahn,

> ‘Hearing one’s own voice almost passes by unnoticed, but once acknowledged it presents itself as a closed system remaining with in the experience of the individual.’ (Kahn, 2001 p.7)

Kahn’s ‘closed system’ equally describes the way the sound appears to the listeners of *Through You* being a uniquely personal experience. In both cases, therefore, attention is drawn to our listening. The experience of the individual’s tuning into their own listening is highlighted, no longer ‘passing unnoticed’ as commented by Kahn, and similar to the attentions drawn to the self-observing listener described in Pauline Oliveros’s work *Ear Piece* (Oliveros in Leley and Saunders, 2012 p.290) as commented on in the Introduction.

It became evident from visitors to the work that when they tried listening to recordings with the transducers on their bodies, the experience was both sonic and tactile. A participant reported putting the transducer on her hand said:

> ‘Mixes sound and touch – like a little hamster vibrating in your hand.’
> ‘I put them on my spine and it almost hurt and I put them on my ear and elbow and it was nice.’ (*Through You)*

Although both people giving feedback were aware that the experience involved them hearing sound, they described the sense of touch. I therefore wondered how much the crossing over of the senses was altering their perception. In their paper ‘The Merging of the Senses’, Stein and Meredith state:

> ‘...For the world is not perceived as a series of independent sensory experiences .....rather, there is an interweaving of different sensory impressions through which sensory components are subtly altered by, and integrated with, one another.’
> (Stein and Meredith, 1993 p.x-ix)

I found in this study that the comments of the listeners expressed surprise on the whole when their attention was drawn to the idea that there was a crossing over of their senses. The way the visitors were able to access the sounds heard only through their body tissue allowed them to focus on these sounds. The perception of the properties of these sounds, unnoticed and unnamed in the course of our daily lives, were brought to light by the sound artwork.

Two artists who explored the idea of the crossing over of senses, and produced work where sound is played into the body of the listener are Bernhard Leitner, with his work *Sound Chair* (1975), and Laurie Anderson with her work *Handphone Table* (1978). In Leitner's work, where he plays music into the areas of the back as well as the back of the legs of a person sitting in a deckchair, his focus is on the planned architecture of the whole space incorporating the room. This contrasts with Anderson's work where she requires the visitor to place their elbows into small holes and their hands over their ears so that the sound travels through the arms focusing the listener's attention on the arm and skull specifically, and the process of the sound passing along from table to ear. Both these works seem to change the listener's understanding of sonic perception. Put in relation to this study, particularly dealing with the effect of sound travelling through different materials, they both pose questions about where we might think of sound as being heard.

I found that participants experiencing the work *Through You* started thinking of things this activity suggested to them when they focused on hearing differently and thinking differently about their surroundings. The first visitor comments they were tracking sound through their own bone structure and the next they were thinking further about the mechanisms of the sound wave reaching their ears.

> 'Really nice great invention, heard by your bones it is my first time to see it.'
> 'Great experience - there will be no use of speakers soon!'
> (*Through You*)

Secondly, in relation to the merging sonic and tactile senses altering our perception of our surroundings. For example one visitor could re-imagine her surroundings by receiving sound through her feet.

> 'I almost wanted them to be huge to stand on them – the transducers.'
> (*Through You*)

To get an understanding from another perspective of how one might think of sound as touch, I spoke with a person who 'hears' with the aid of vibration. During the course of making the work *Ground Sound* (See Chapter One), I interviewed Gemma Smith, a visitor to the installation who is profoundly deaf. The sound from the ground heard in the car via the subwoofer consisted of audible and inaudible low frequencies. I have quoted the responses she made here in this chapter, because

the ideas generated from her comments for the work *Ground Sound* relate particularly to ideas of sensing vibration. The similarity of this idea in these two chapters highlights a continuity of process in the study. Her comment below reveals a parallel between her experience of vibration and a hearing persons' experience of sound.

> 'Sometimes I go through a whole host of vibrations everyday, and when it gets too much I do want some piece and quiet. Bit like you having a particularly loud day? I can feel the bumpy road but the smooth surface is quiet.' (Excerpt from interview with Gemma Smith)

In the course of deciding which questions to ask her, I imagined myself sensing vibration instead of sound, which sharpened the awareness of my own senses. During this process, and from the responses of Smith, I formed a clearer understanding of the body as a 'receiver' and an indication of the degrees of sensitivity she was able to experience in everyday life.

Although my own senses were becoming more sensitized, unlike the fish sensing sound through vibration within their bodies, I found paying attention to sound coming from within my body an unusual thing to do. More usual, when fingers in ears or headphones shut out external sounds, is the internal sound from either our blood racing when our heart pumps fast or ringing sounds of some sort from tinnitus. In the work *Through You* I'm inviting the visitors to become more aware, and question which sounds they hear from within and which sounds from outside.

> 'When you put it (sound) into your body you start to feel more mechanical about it – is it 'spatial out' or 'spatial in?' (*Through You*)

Steven Connor comments on our usual habit of hearing, when commenting on the ears' function. In his talk *Auscultations: Listening In* (Connor, 2010) he comments that the ear is 'half anatomy and half imagination'. Connor discusses the fact that we don't often focus on where we imagine sounds are heard. Are they 'heard' in the ear, or in the brain - because it's registering the ears' hearing of sounds? In addition to that, when identifying the location of the source of the sound, if they are internally heard, like the sounds in *Through You*, or indeed tinnitus as discussed by Connor, it is confusing to guess where they're from. Are they as the feedback above comments 'spatial out' or 'spatial in?'

How can we geographically map the source of the sound in our imagination? When tracking the source of these sounds we hear in our imagination, there is a relationship between sound and space. In thinking bout the 'spatial out' or the 'spatial in' question, where is the space suggested in sound? Connor goes on to define this offering me a way of thinking further about the experience.

> 'If we can say space is described by sound and sound is the space in which it occurs, it causes a disruption in our habit of listening, and listening to inside generated sounds brings a focus to what it means to hear sounds.' (Connor, 2010)

Connor identifies three components to the process of listening to sounds in terms of space, place and imagination and comments,

> 'Sound is the space in which it occurs...,' He goes on to suggest that,
>
> 'Place is defined, located, actual,
>
> whereas space is possibility .....'.
> (Connor, 2010)

Given Connors' assertion that sound and space may provide the ingredients for 'possibility' and after my experiences during this study, these 'possibilities' will suggest evolution in the creation of space via the imagination. Connor's ideas therefore reinforce the idea that the imagination of the visitors to *Through You* is a main part of this sound artwork working together with the physical properties of the experience of sound and vibration.

In response to the research question *How can the physical properties of sound become manifest through the production of Sound Artworks,* the physical properties of sound in this artwork give rise to questions posed by particularly hearing the sounds internally, through inside of our ears rather than externally from the air. The questions posed by experiencing this work instigated inspiring and sometimes personal comments from the visitors, sometimes concerning their orientation.

'I had a feeling that I doubted my own sense: I felt spooked cos it sounded, when I put it on my head, very loud and I had to ask Aya if she could hear that.'

'Putting the transducer on my skull I had the experience of hearing sounds also on the other side of my head as if from an external sound source but with nothing there – phantom sound!'

'I felt it intrusive – very powerful....'
(*Through You*)

The exploration made with the transducers were all uniquely individual and personal to the visitors and as Douglas Kahn commented,

' …remaining within the experience of the individual'.
(Kahn, 2001 p.7)

The disorientation and habit disrupting aspects, along with the personal and very individual nature of the experience expressed by the visitors, inspired me to be more challenging in subsequent works in the study in terms of the interaction of the visitors and the generating of imaginatively conceptual ideas, aware that as Stephen Connor comments,

'…the ear is 'half anatomy and half imagination',
(Connor, 2010)

Chapter Five – You Are Here

> ‘For our house is the corner of the world. As has often been said, a real cosmos in every sense of the word.’ Gaston Bachelard (1958 p.4)

Bachelard alludes to the fact that the house is essentially our very own ‘cosmos’, containing our essential world, familiar and understood, and for all those reasons setting the last artwork in a house was appropriate. The aim of the work *You Are Here*, was to locate a series of experiential sound artworks in this familiar setting, therefore encouraging those who experienced it to re-evaluate their own experiences of home.

In this artwork the house becomes like a listening box. It allows the visitor to access sound they couldn’t access before stepping through the door. Listening inside the house, the sounds expand the range of the visitors’ hearing by amplifying and making audible: sounds from ourselves, sounds travelling great distances through the earth, and sounds from beyond our earth’s atmosphere.

The familiar context for the work, a house, creates the potential for the visitor to go back to their own house and consider their different listening experiences, reassessing their relationship with the sounds of their house. They now understand that there are at least three sonic worlds that they can’t normally hear, but they can now imagine because they have heard them in this artwork. Stepping back into their own kitchen, boxroom or attic, they would think of these places differently. The work would create for the visitor, a new knowledge, a new understanding of their place, their home, in the ‘Sonosphere’ of the sounding universe.

> ‘The unnoticed house has our attention as the quiet mediator of the familiar; we know what we understand by ‘house’.’ (Words from my journal).

Outside the house specified for the sound artwork, visitors found on a ‘for sale’ sign, the text *You Are Here* (See figure 26), indicating they had reached their destination and pinpointing, like an Internet mapping software, their location on the map of the earth.



Figure 26 - Arrival

Once inside, visitors to the house had clear instructions about the spaces they could enter and couldn't enter (See figures 27,28 and 29). The business of the house went on as usual. A text was displayed on the wall. (See figure 30)



Figure 27 – Information on arrival



Figure 28 - Welcome



Figure 29 – No entry

Table of comparable speeds of sound

The Speed of sound in air at 20c is *343 m/s*

In water the speed is *1,433 m/s*

But for Ice the Speed of sound is *3,990m/s*

Speeds of sound through seawater *1,530m/s* depending on the salt concentration

Speeds of sound through your body tissue is *1,470m/s*

Speeds of sound through your brain tissue is *1,490m/s*

Speeds of sounds through kidney and liver tissue is *1,450m/s*

But the speed of sound through the spleen is *150m/s*

Speeds of sound through wood particularly Pine is *3,320 m/s*

Speeds of sound through Oak is *4,470 m/s*

Speeds of sound through Douglas fir is *4,800 m/s*

Speeds of sounds through Ash is *4,670m/s*

Through Maple is *4,110m/s*

Through Sycamore is *4,460m/s*

And through Cork is *500 m/s*

Speeds of sounds through Brick is *3,650m/s*

Speeds of sounds through Concrete is *3,650m/s*

Speeds of sounds through Granite is *3,900m/s*

Through Slate is *4,500m/s*

Through Clay rock is *3,480m/s*

Speeds of sounds through Marble is *6,150m/s*

And speeds of sounds through Window Glass, as opposed to Plate or Pyrex Glass, is *6,790m/s*

Speeds of sounds through Beef is *1,550m/s*

Speeds of sounds through Olive Oil is *1,430m/s*

Speeds of sound through Rock salt is *4,4780m/s*

(UT Materials Properties Tables, 2013)

And through Petroleum is *1,290m/s*

Speeds of sounds through Bakelite is *2,590m/s*

Through Peanut oil is *1,460m/s*

Through Linseed oil is *1,770m/s*

Through Turpentine is *1,280m/*

Speeds of sounds through Nylon is *2,620m/s*

Through Polystyrene is *2,670m/s*

Through Teflon is *1,350m/s* and Neoprene *1,600m/s*

Speeds of sounds through Lead is *1,158m/s*

Speeds of sounds through Rubber *1,600m/s*

Speeds of sounds through Steel *6,100m/s*

Through Aluminium *6,420m/s*

Through Copper *3,910m/s*

Speeds of sounds through Silver and Gold is *3,600m/s* and *3,240m/s* respectively

Although Glass, Steel and Aluminium are between *6,000* and *7,000m/s* -

The speed of sound through Diamond is *12,000m/s*

Speeds of sounds through Porcelain *5,600 m/s*

Speeds of sounds through Perspex *2,860m/s*

Speeds of sounds through Diesel Oil *1,250m/s*

Through Tin *3,300 m/s*

Through Cast iron *3,500m/s*

And through Zinc is *4,170m/s*

Speeds of sounds through Carbon Dioxide *258m/s*

Helium *970m/s*

Hydrogen *1,280m/s*

Methane *430m/s*

And through Oxygen at 20c is *328m/a*

Figure 30 - Sounds' speeds list

First Part: Sound in the Kitchen

I will outline the decisions that brought about the installation in the kitchen, including investigating the source of the sounds amplified, the choice of equipment used and the comments from the visitors that informed a response to their experiences.

The visitors, on approaching and entering the kitchen, experienced sound and vibration that caused the kitchen, its floor and fittings to vibrate. These vibrations were picked up by a geophone (SM24) placed in a meter deep hole in the garden (See figure 31). This was sent to an amplifier (VX 1000W American Audio) and then to a large subwoofer (200W Pyle Pro PDW 21250) in the kitchen (See figure 32). A second geophone (SM24) sent vibration to two transducers (Mini LFE 250W Buttkicker) on kitchen shelves via an amplifier (300W BKA-130-C), which mainly shook the crockery on the shelves (See figure 33). A video monitor near the sink showed the geophones at the bottom of the hole in case it was too wet to go out in the garden to see them.

The source of the sounds

The source of these amplified sounds were local (a few meters away), mid range (a few kilometers distance) and long range (several thousand kilometers). A combination of these vibrations affected the kitchen.

Local sounds

The imagination of the visitors was called upon from the outset. What were they experiencing and where was it coming from? To clarify where the sound was coming from and that it was live, not a recorded sound, the geophones were visible in a deep hole in the garden. Like the work *Ground Sound*, the visitors could see the source of the locally made sound as the impact of people stamping their feet near the geophones could be felt and heard, whilst being viewed through the kitchen window. Unlike *Ground Sound* there was written information provided to give some indication of what they were hearing, and why they would think they were hearing more than the very localized sound from the hole in the garden. The logic of why I should do this came from the experience of an earlier project in the study.



Figure 31 - Geophones (Photo Paul Whitty)

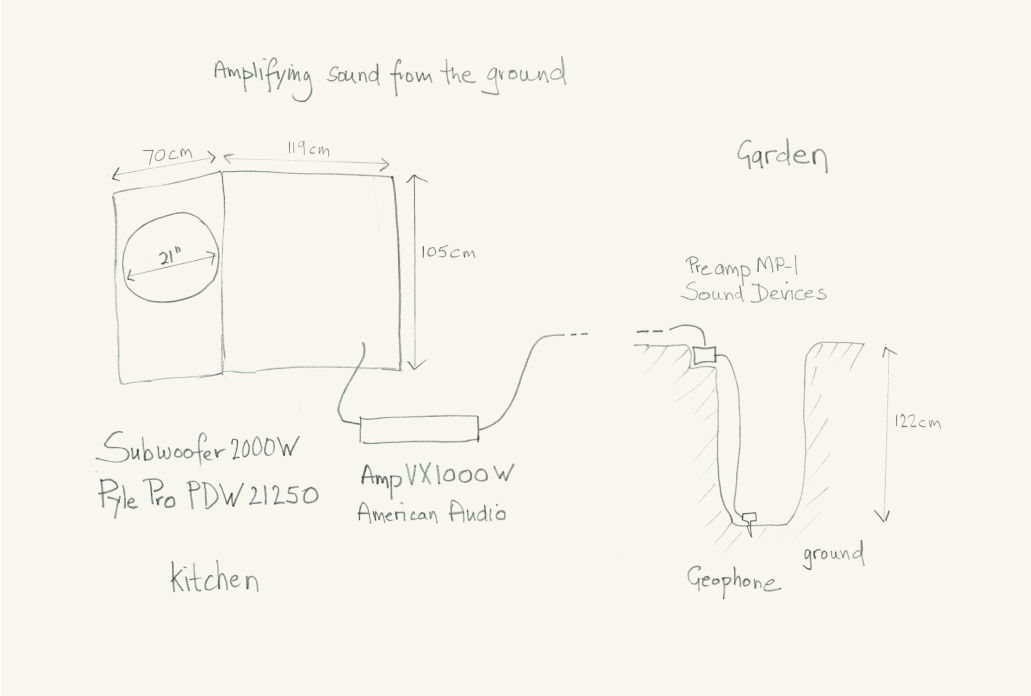


Figure 32 – Subwoofer system

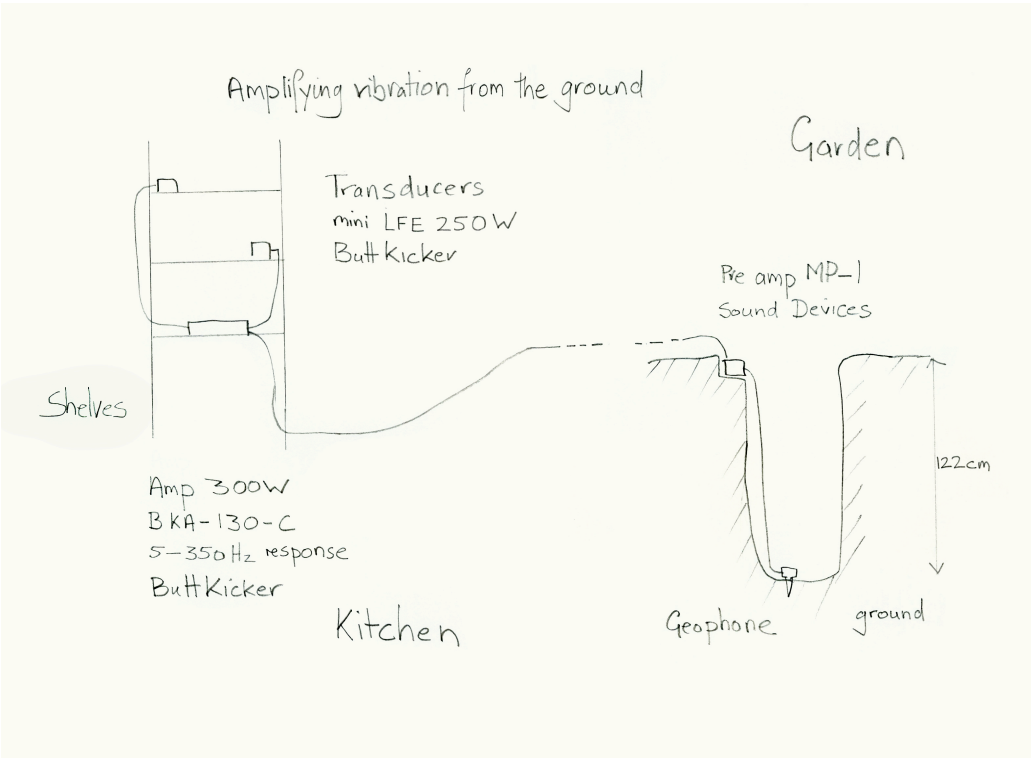


Figure 33 - Transducers system

Mid-range sounds

Whilst collaborating to make the work *Bury Your Love Like Treasure (*2012) with artists Professor Paul Whitty and Emma Welton and contributing to the research of their project, I tested the ground for sounds with a geophone and resonated them through a double bass (See figure 34). I imagined, as we were far away from places I thought would impact on the geophone, that we wouldn't hear much or any sound through the equipment. In effect we heard a great deal of sound, and wondered where it had come from. When looking for possible places this sound might be coming from on the map, we found there were main roads and a railway line 4.5 and 2.4 kilometers away respectively. We could not see these places although we knew they were there, so the sound we were hearing extended our landscape to encompass them. Our landscape now encompassed the places we couldn't see. In the installation in the kitchen, mid-range sounds were indicated as the sounds of Bristol from several kilometers around.

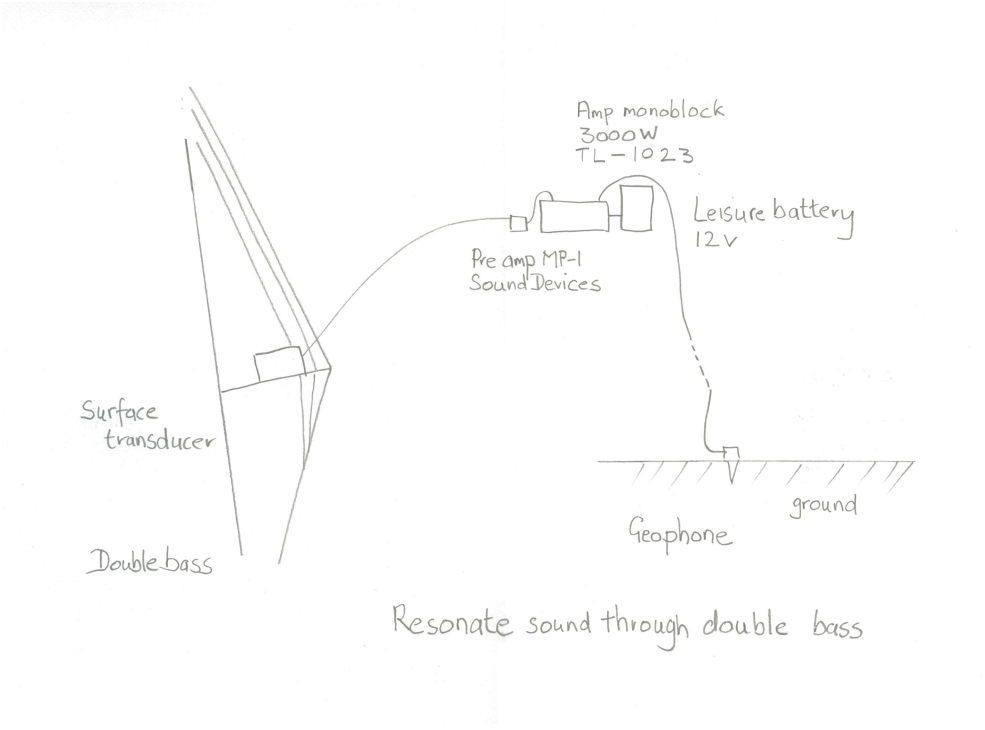


Figure 34 - Double bass

Long-range sounds

To indicate, in the kitchen, that it was possible for sounds to travel in the ground over different distances from places the visitor could think about but couldn't see, I provided some information about the behaviour of sound travelling in the ground; how fast and far sound waves travelled and a daily up date of the latest most substantial seismic activity reported online by the United States Geological Survey (USGS, 2014). While not being directed specifically to think what the sounds should be, those encountering this work would encompass ideas in the information, which suggested how the underground sound could be coming to their ears. The balance between the visitor imagining where they thought the sounds were coming from, and the actual properties of sound and vibration that the visitor physically heard and felt were both components of the work.

Equipment

Since making the work *Ground Sound* I had attempted to see if I could identify the exact source of the sounds I was hearing from the ground, which would clarify to the visitor the distance the sounds they heard had travelled. In the next section I will describe how I investigated the ground through which the vibration was travelling and what equipment became appropriate to use for the installation.

Ground as a conducting material

Using a house in a city could show that not just a mountaintop or desert can be a place to connect us to our 'expanded environment'. I asked Professor Helffrich, Dept. of Earth Sciences, University of Bristol, whether it would be possible to listen to seismic sounds from under a city, and which, out of Bristol and Oxford, would be most effective. The answer was that if I didn't want to make accurate scientific calculations I could go to either place. (See figure 35 and 36 for the subterranean strata of Bristol and Oxford). Helfrich also said,

> 'Site conditions in Bristol are slightly better than Oxford due to the deeper soil and sediment layers in Oxfordshire, but there is more human-generated noise.'
> (Communication vie email from Professor Helffrich - 2012)

As I was interested in both natural seismic sound and man-made sound, Bristol was the best option, so I located the work there.

Figure 35 - Geological map of Oxford - Grid Ref: 453577, 206709

Figure 36 - Geological map of Bristol Grid Ref: 359393, 175078

Identifying low frequency vibration

In my investigations to understand further the way I could identify and show the different frequencies and distances of the sound travelling to the kitchen, it became clear that the aural and tactile senses that could be experienced with the use of a geophone were more central to the work than the visual data that could be shown by a seismometer. Specifying the Geophones I had, (SM24- Applications: 2-D & 3-D seismic exploration with bandwidth from 10 Hz up to 240 Hz, although I subsequently tested sensitivities to 1Hz), I had asked John Laughlin (BGS) how I might identify different frequencies of vibration in the ground. Here is a précis of what Laughlin said in response:

- To identify a signal from a long distance away like a 1Hz frequency you would need to see that it was long a period signal on a 'chart type display'. This would be hard to see in the small display window of an oscilloscope.

- A geophone would be less sensitive than a seismometer for detecting low frequencies, and is designed to also pick up higher frequencies like man-made sound.

- BGS stations monitor seismic activity throughout the UK. If I wanted them to help me identify low signals received in Bristol, their stations would have to be very close to my location to identify it. (Email correspondence 2012)

The seismometer would be the equipment for plotting and identifying the data from low frequency vibration accurately, but would not deal with the higher range of frequency I was interested in showing, and the immediate visceral experiences I wished to create. This information from Laughlin therefore allowed me to see the distinction between the geologists need for accuracy and the artists' need to create an experience. I decided that although I would not be able to identify the live signal with the geophone, I could give the visitor an approximate idea of the activity at that time (UGS, 2014). I could find out what seismic activity was taking place by going online. Importantly, sound artist Tom Pod and I identified a 1Hz reading, picked up in the Bristol location with an oscilloscope, so I could indicate in the artwork, we were receiving 1Hz seismic levels of frequency (See figure 37).

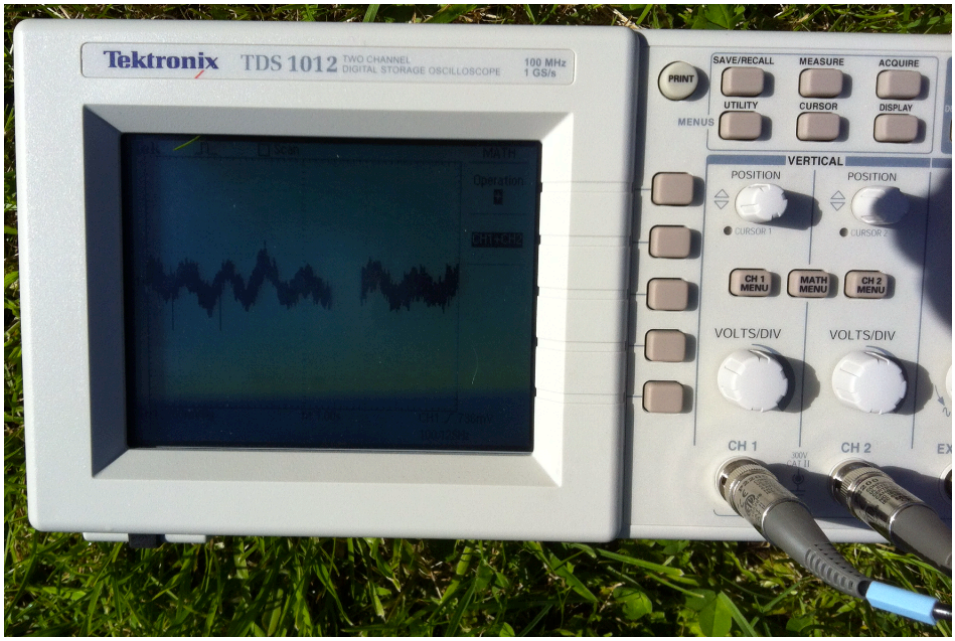


Figure 37 - 1Hz oscilloscope reading

Constructing the installation

I needed to find out how I could create an experience of low frequency for the visitors to the installation, and what equipment I could use to work with the geophones I had already. Perhaps a large transducer on the wall to vibrate the house structure, a wardrobe with a transducer directly on to the sides with a taut membrane inside that would vibrate or a large bass speaker cones either in a wardrobe or speaker cabinet would work. I went first to test the geophones I had with the largest speakers I could find.

From my previous conversations with David Carugo from the Department of Technology at Oxford Brookes University, I had found that the specifications for many amplifiers and speakers advised they would only work above a range of 25Hz. However testing a speaker (Yamaha MSP5A) with a 4Hz sine wave signal (generated from a phone) where its specification showed the lowest frequency would 'not be suitable below 25Hz', we found that this 4Hz vibration was evident on such a speaker as an inaudible vibration. This meant it would be possible to use a similar speaker for my installation.

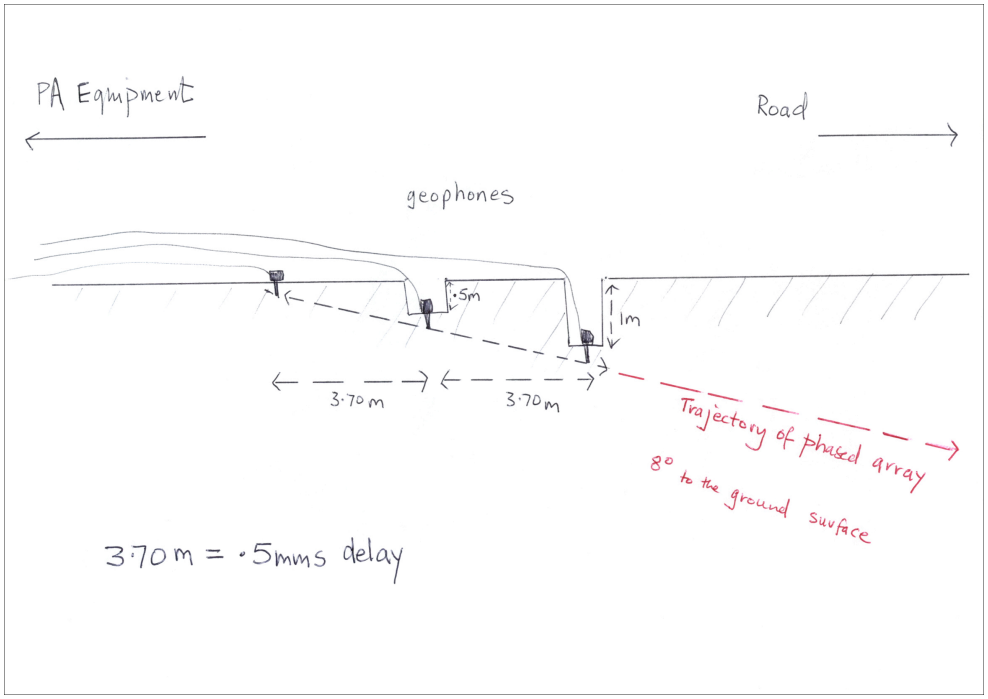


Figure 38 - Geophone array 1

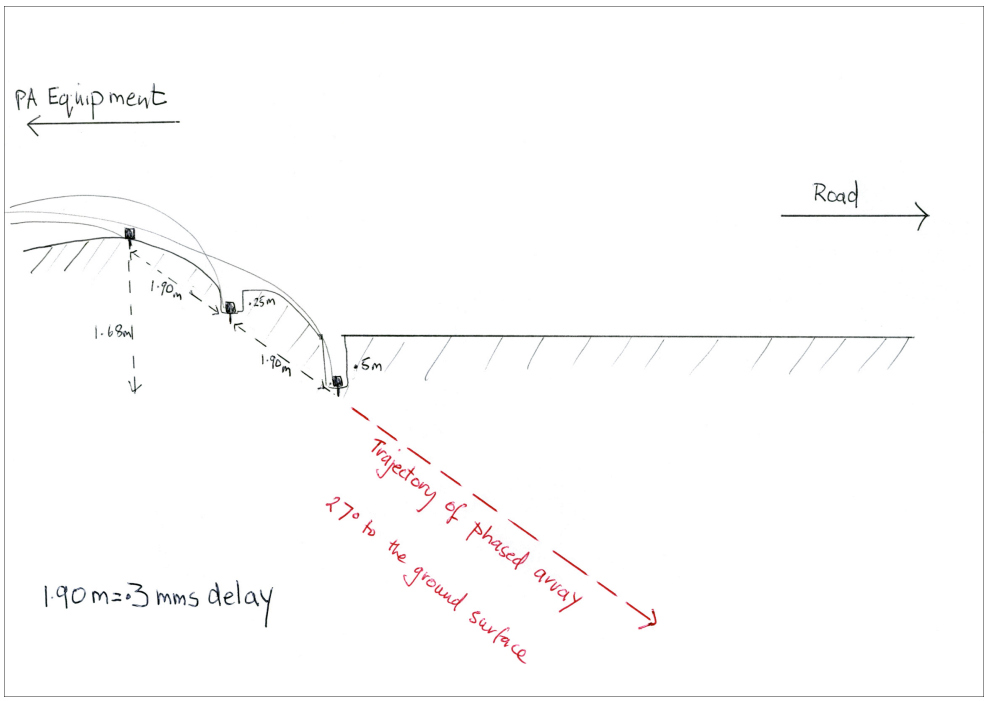


Figure 39 - Geophones array 2

To test if we could maximize the strength of the signal from the ground, we tried placing multiple geophones in a line or 'phased array'. The signals would all be heard through the speaker at the same time making this signal stronger. The mixing desk would facilitate appropriate relative delays to achieve this (See figures 38 and 39) (*Deep Sounds,* 2012). We found that the array did make the signals stronger, but would need a substantial amount of equipment in the house to do so.

Reducing my options allowed me to focus on what I did not want from the installation experience with a live feed from the ground. I found that the larger transducers that might shake a house wall, such as the Aurora AST-1B-4 or the Crowson TechTES100, were out of my budget; the wardrobe ideas would take more time than I had to test; and although I was kindly offered the use of the Oxford Brookes Department sound system, I realised I did not want the house to be swamped with a huge amount of equipment but rather have a system that indicated how the sound was introduced without transforming the nature of the house.

All these steps in my methodology brought me to the conclusion that I would therefore have two elements in the kitchen producing the effect I wanted of sound and vibration amplified from the ground: speaker cone in a cabinet to create sound and vibration, and a pair of transducers attached to shelves that would vibrate the contents of the shelves. I had previously tested the effect the geophone had when vibrating directly on crockery (*Tea Tray Investigations*, 2012) (See figure 40). Visitors could touch both items if they chose to do so, and both items might create associations for the visitor (See figures 41 and 42).

To make the speaker and cabinet, I asked the advice of Toby Heys, from John Moores University – Liverpool, who had just made some bass speakers for *Eyebeam – Collaborative Work* (Heys, 2013). With Heys' instructions on an online web page (Instructables, 2013). I put together, with the help of a colleague in Bristol, Georgina Shire, a 21inch speaker cone in a box cabinet of the right dimensions (See figure 41).



Figure 40 – Tea tray vibrating

My investigation for equipment helped me shape the installation and, at this point looking back over the study, define the role of equipment in the study. I could see that it is possible to infer that the work consists primarily of two technical sets of apparatus: one beginning with a geophone, the other ending in a transducer. Both are the means of listening to the journey or transit of the sounds. The subwoofer in the car and the kitchen, the transducers on the double bass, the crockery and the tissues of the human body are conveyors of the properties of sound and are the central feature of the works that connect us with the natural materials through which sound can be heard and 'felt'. In the study a large part of the methodology is concerned with what equipment can be used or is suitable to enable the artwork, and the importance of the equipment in this way defines the practice in this study.

In conclusion to *Sound in the Kitchen* it is the material or substance, in this case the ground, through which sound is experienced that creates the ideas associated with the outcome of the visitors' experiences. The visitors questioned their senses and their assumptions of what they expected as 'normal', when comparing it to what they then experienced as 'abnormal'.



Figure 41 – Subwoofer



Figure 42 - Transducers

> ‘It’s that sense of the earth – we assume it’s solid under our feet but it’s moving and shaking and quaking all over the place, and therefore we’re not on stable ground..... I get from it a sense of danger.’
> (*You Are Here*).

> ‘... you go inside into the kitchen past the dining area, and you have this massive box and it’s almost as if your eyes are playing something on you because you can see it palpitating. .... I had to touch it to understand what’s gong on, in order to understand why my eyes are seeing the whole kitchen moving.’
> (*You Are Here*)

The checking of the source of the sound in the kitchen, by stamping the feet near the geophone, caused visitors to question what they were hearing and feeling and led them to question where the sounds were coming from. Responding to the research questions with that in mind, I was suggesting in *Sound in the Kitchen*, that there was a geographical journeying of the sonic properties experienced in the room. I wanted to create a situation where the visitor would be prompted by the unusual ‘instability’ of the usually stable fabric of the room to imagine places suggested by these sounds they heard, from underneath the neighbours’ gardens and the city streets where they could see activity, as well as deep within the geological strata below the city where the house they stood in had its foundations.

Second Part: Sound in the Boxroom

Visitors came into the room on the first floor and saw a table and an empty chair placed in front of it, with instructions written on the wall (See figure 43). Although visitors were free to experiment, it needed to be clear in the instructions what the visitor needed to do and what the equipment was for. For that reason the instructions were a simple drawing rather than a photograph (See figure 44). Visitors listened to their heartbeat through the equipment, whilst the sounds of the house filtered into the boxroom from above and below.

Using a stethoscope designed for listening to a heartbeat, a small lapel microphone was placed in the tube down from the membrane that picks up the heart sounds from the skin of the visitor. The idea came from sound artist Diego Stocco, where he fitted a microphone to a stethoscope to pick up sounds from a tree he was using as percussion (Stocco, 2013). The microphone, in our system, was then connected through a mixing desk to a small amplifier that in turn was connected to a transducer. The visitor holding the stethoscope membrane on their heart could, with the other hand, place the transducer on another part of their body to hear the sound of their heartbeat conveyed through their body to the inside of their ear (See figure 45).



Figure 43 - Box Room (Photo John Skinner)

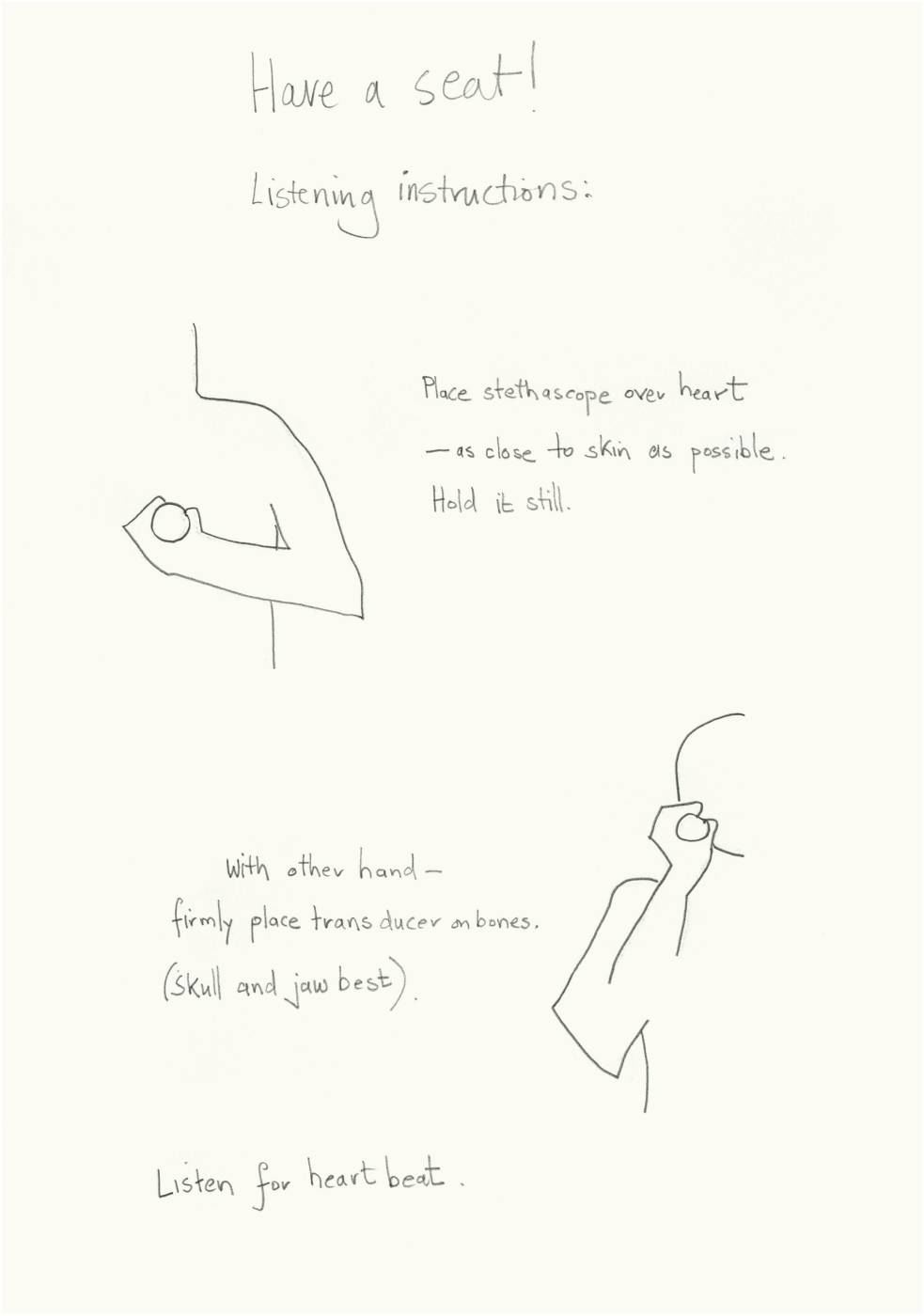


Figure 44 - Instructions

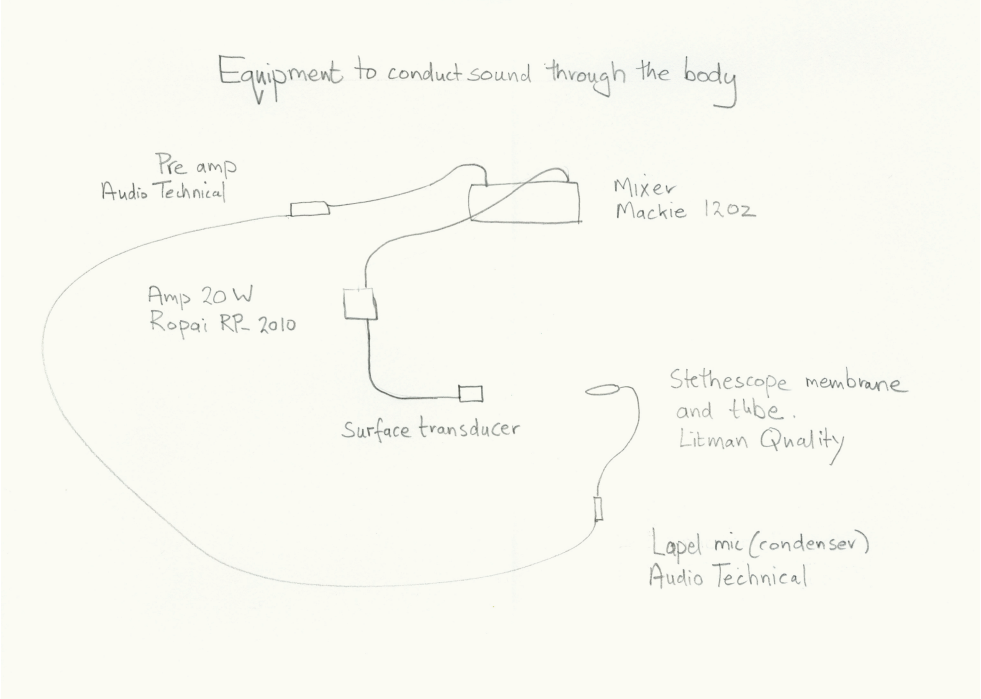


Figure 45 - Stethoscope / transducer system

Visitors commented on the unique experience:

> 'I felt that the way the sound came to me in the heart room, it was a very physical sound. I could make a drawing from that sound. I got a very clear idea - a bit like getting a sonar scan – it's like 3D imaging but sound.' (*You Are Here*)

The comment above shows how the visitors' perception of the images suggested by the sound they heard, was a spatial one. Thinking about their combined visual and sonic experiences allowed them to describe their experience in terms of an imaginative mixture of senses. Like the mixtures of senses described in the work *Through You* (Chapter Four), the experience of the sonic and tactile heartbeat caused as Steven Connor describes,

> 'a disruption in the habit of hearing.' (Connor, 2010)

Here was an indication that these works in the study show we can listen differently to the soundscape around us, and that there are both soundscapes and senses to sense that we don't usually pay attention to, and that we can newly experience.

Focusing on listening to their bodies also reminded people of familiar procedures when being examined for medical reasons. Visitors to *Through You* (Chapter Four) and *You Are Here* commented on how the metal transducer and stethoscope when placed on the body, reminded them of this.

> 'There was a very medical feeling to it.' (*You Are Here*)

Procedures recalled vividly from hospital visits, and memorable images simulating medical scenes that emphasize the mechanical processes of the human body are used to strong effect in the work of artist John Wynne in his work *Transplant* (2010). In her paper *Touch as Listening: Pulse Project* (2012), Michelle Lewis-King compares Wynne's work with that of Marco Donnarumma's, *Music for Flesh ll* (2012) where he listens to sounds in the body live. The performative styles of Wynne and Donnarumma differ from that of Lewis-King's interactive research, and all three works differ from *You Are Here* where visitors initiate their own explorations (See figure 46). The work of all four emphasize the physiological properties of the body, and play on the general idea that people are both repelled and fascinated with the functions of their own body.

Thoughts from the experience of one room affected those of other rooms. In the comment below images are created from listening to the heart, not an image of the organ the heart, but borrowed from ideas formed in other rooms.

> 'It was quite incredible to hear (your own body) this thing in the distance almost in the same way that you hear the cars in the distance. It didn't feel like a dissimilar thing to the earthquake – it was like an inside earthquake.' (*You Are Here*)

The interlinking relationship of the three rooms came about when I decided to have only three rooms in the artwork. When considering *You Are Here*, I wondered if I should include rooms involving water experiences as I had worked with sound in a bathroom – *Through the Bath Water* (Chapter Three). It occurred to me, however, that the *Sound in the Boxroom* experience should become the essential middle part, our self-listening station on the first floor placed literally and correctly between sounds from thousands of kilometers stretching down into the ground



Figure 46 - Heartbeat listening

beneath (Kitchen), and sounds from millions of kilometers stretching up into the universe above (Attic), described in the last chapter.

> ‘I loved that you could listen to your own heartbeat, as if to reassure yourself that although you are tiny compared to the other things you are listening to, you are there and alive in all of this vastness of earth and space.’
> (*You Are Here*)

Third Part: Sound in the Attic

Before I describe Sound in the Attic, I will outline the important aspects of its preceding research findings that led me to make the work, describing how the ideas of Pauline Oliveros influenced the study when she described the term 'Sonosphere', what family of sounds it described and how I began to see how to work with them in an artwork for this study.

Research findings

Like the 'Sonosphere' idea created by Pauline Oliveros (Kahn, 2013 p.175), I have come to think that different signals, including those from outside the earth's atmosphere that are not sound waves, can be thought of as 'sounds' from our environment, and here I include the expanded environment of space. My research into signals from outside the earth's atmosphere has required me to look at the processes by which these signals have been able to be received on earth. The transit of sound discussed below, represents the journey of what we subsequently hear as sound, travelling from source to perception.

In the last chapter, *Through You*, the transition process involved sound waves travelling through air, to bone, to 'impulses', or 'neural energy' to the brain. (White and White, 1980 p.101) However, in this chapter the transition starts with natural sources in space, then to telescopes, to computers and then to our ears. I considered radio waves, microwaves, sound waves and cosmic waves in the process of this study, and below is a comparison of their differences (See figure 47). They have in common both wave-like and particle-like properties (Breithaupt, 2000 pp.636 - 8). A detailed comparison of these wavelengths is written about in Guy Murchie's popular science text (Murchie, 1961 p.450). Signals on the electromagnetic spectrum, such as radio waves, need to go through different processes to arrive at our ears as sound waves. The radio wave arriving in the telescope and subsequently the computer becomes data and in the computer is assigned a sound that can be heard.

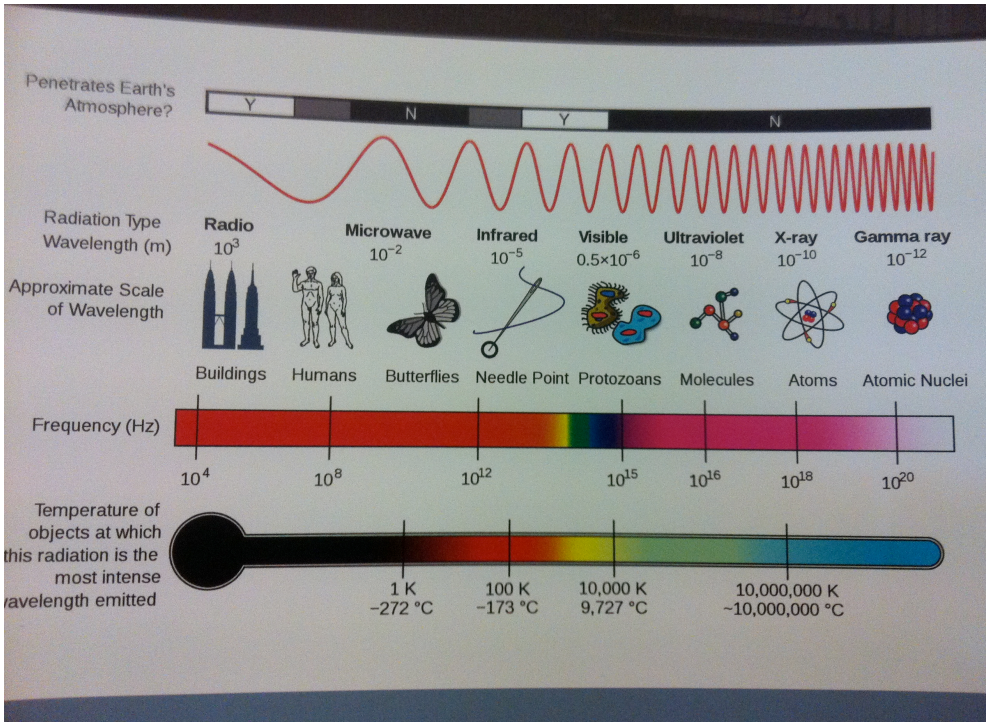


Figure 47 - Science exhibition poster

It could be said that signals from the electronic spectrum cannot be 'heard' and therefore are not 'sounds'. I would point out that it is evolutionary happenstance that our human ears, and senses, work in the way they do, and creatures that happen to have evolved differently from us are able to detect signals on the electromagnetic spectrum. Our human senses are 'restricted' compared to say, a bat that is able to hear much higher ultrasonic frequencies than humans. Bats of various species are reported to be able to hear from 1kHz to 150kHz (Berg and Stork, 1995 p.58). Lizards and snakes can see in the ultraviolet and infrared ranges of the light spectrum we cannot. (Kaplan, 2013).

We can, however, use equipment that enables us to interpret signals that cannot be sensed solely with human ears, such as the radio telescope or the deflector dish, that are conveying signals in different ways. We are used to a sound system where technology conveys to us information via electronic cable, magnetic coil and speaker. I could say that the processes of the familiar Hi-Fi system and less familiar radio telescope technology could both be facilitating –

> '.....the use of non-speech audio to convey information'
> (Candey and Schertenleib, 2013)

- that informs me of my environment. In using technology to understand a signal, how far can we interpret it before we consider that it is a fabrication or exaggeration of fact? The sound we hear in our ears is altered, interpreted and re-assigned before it gets to our ears through the environment; for example, when it travels through walls, reverberates round buildings or tunnels, is damped down by soft materials, is made louder or softer by air pressure or the temperature it travels through. Sound is altered and interpreted when it passes through a sound system, where the processes, not least the size of the cone or speaker, alters the sound. Lastly the physiology of our ears and their sensitivity also play a large part in the reception of the sound we hear,

> '...the boundary between sound and non sound is based on the understood possibilities of the faculty of hearing-' (Sterne, 2003 p.12)

My contention is that there are different and equally valid ways of interpreting signals from our physical surroundings. My research has led me to recognize that different signals we receive, either on the light spectrum or as sound waves, are all signals conveying information to us. Artist Jem Finer in his residency at the Astrophysics Department of Oxford University writes:

> 'Working in the Astrophysics department, one of my interests was radio astronomy, a point at which invisible information becomes tangible, an extension of our senses into wavelengths below the optical.' (Finer, 2005)

The fact that signals from outside the earth's atmosphere need to be interpreted for me because they started out in a form I am not able to sense as a human, does not, for me, detract from them being signals I can experience to understand my environment.

Exploring the idea to work with live signals from outside our atmosphere and to incorporate them in an artwork, led me to understand more about both radio waves and Cosmic Microwave Background Radiation (CMBR). Advice from Paul Hyde at the National Space Centre Leicester (British Astronomical Association, 2011) in regard to radio waves I could receive was,

> ....'solar radio bursts can be received with a commercial short wave receiver and a suitable antenna but, as with (radio waves from the planet)

Jupiter, they would be infrequent and would not appear to order, which would make demonstrating them difficult.'

Dr Tim O'Brien, Director of Outreach Programmes at Jodrell Bank (2012), suggested I might work with CMBR as identified by analogue TV (See figure 48), to show evidence of a signal from space. Practical tests to show evidence of the CMBR that we can pick up on an analogue TV (Whittle, 2013) were made, and in the process of developing these ideas for an installation, I struggled to think of a way to make the experience of hearing and seeing evidence from the CMBR self-explanatory. To show that the signals were coming from an extreme distance needed the visitors to read an explanation of the theory of how they might do that, and this would detract from the works' impact.

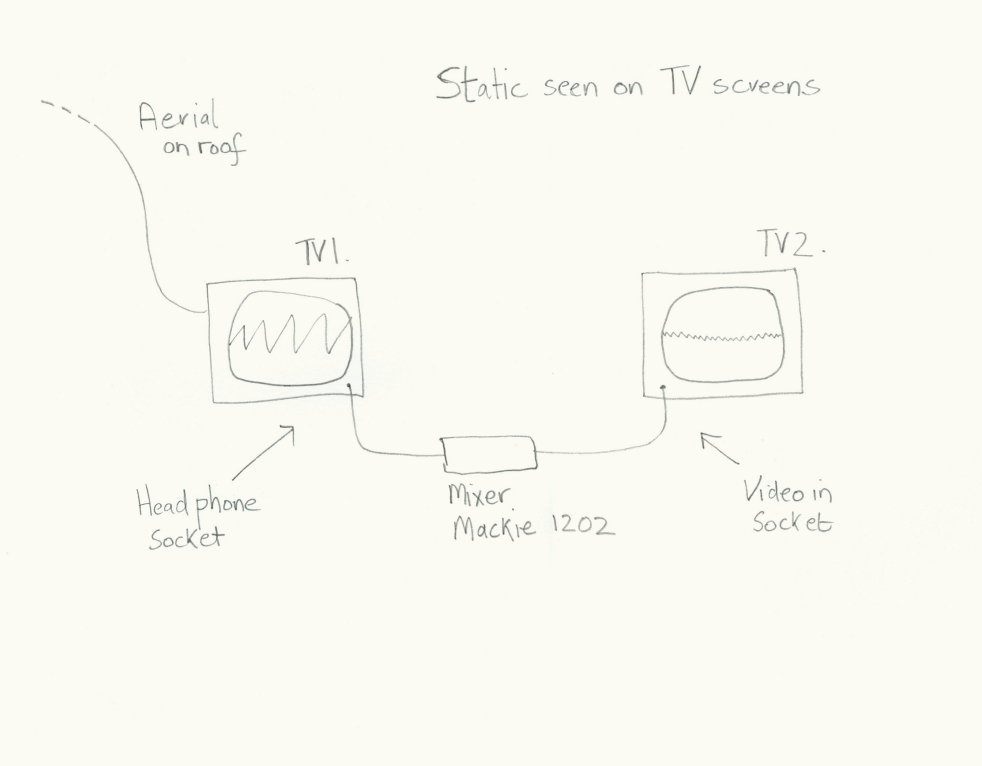


Figure 48 - CMBR on TV

Looking at other artists working with cosmology where complicated information needed to be understood for the clarity of the work, I felt that where there was enough visual and cultural understanding, the work would have impact. For instance in the work by Brian Duffy *The Optophonic Lunaphone* (2007), where he converts light from stars to sound heard by the visitor, the visitor can see both the telescopes and the sound equipment and make assumptions from their own understanding about what is going on. *Earth Moon Earth* by Katie Patterson (2008)

requires the visitor to read that what they are hearing is radio waves being 'reflected from the surface of the moon'. This is easy to understand and the experience has impact. At the Royal Society Summer Exhibition (2012) in London, I was able to see a Cloud Chamber in action which showed evidence of the remnants of radiation trails: muons, that rain down through the earth's atmosphere. Due to the impact and immediacy of the experience of seeing the evidence of cosmic rays (now muons) live, I became interested. This subsequently led to me hearing about a project from Leeds University researching Cosmic Rays (Bull, 2012).

> 'Cosmic Rays are the remnants of high-energy particles that start life in deep space. They are thought to have come from jets of material launched from super-massive black holes and the remains of supernova explosions.'
> (Email communication from Dr. Edmundson – 2012)

The detectors form part of the UK-wide project CORUS (Kings College London, 2013). Ilford County High School, is involved in CORUS, and I subsequently collaborated with them to stream data from muons, detected by their school's detector boxes.

I was aiming to create an installation where a visitor would understand they were experiencing a live sound interpreting a signal coming from outside our earth's atmosphere and originating light years away. My own research had required me to think about the distances between where I was and where I was aware the signal was coming from. I questioned Dr.Paul Edmundson, the Head of the Physics Department at Ilford County High School and a former research physicist, about these exact distances that are explained further in the next part of the Chapter. These ideas were very exciting, and I believed I could tap into my artwork visitors' imaginations to get them to think of themselves in a unique time/space relationship with the universe – as I had. Honor Harger in her talk to the Lift 2011 conference commented,

> 'In popular culture there is no experience of space through sound'.
> (Harger, 2011)



Figure 49 - Listening to sonified rays

The sound in the Attic

On the stairs approaching the attic there could be heard intermittent 'electronic' sounds coming from the attic. In the attic room was an empty chair strategically placed under a skylight and tilted back to allow the occupant's eye line to gaze up into the sky directly above the house (See figure 49). Up to 2 -3 minutes of silence occurred between sounds from three speakers spaced round the small attic facing towards the chair. In the silence from the speakers, quiet sounds from round the house, garden and surrounding city could be heard coming up through the house and in through the skylight.

In presenting the work in the attic, decisions were taken about how the immediate experience of the visitors could 'speak for itself', and how much written information regarding the nature of the signals and their transit, should be available. The aim was to give the visitors as much of an idea visually of the space above the house that they were 'listening up into'. Information about the sounds and their possible sources were visible in the room. When writing and drawing the information to accompany the work, it required me to question what pictures I had in my own mind of the sound sources I was indicating. Although information about the works needed to be conveyed, I did not want to interrupt the visitors' process of imagination - about the place the sound had come from - instigated by the immediacy of the real sound source they were experiencing. I hoped the language used, especially the term 'cosmic rays', would have associations for the visitors of materials they knew were from outside the earth's atmosphere without having to explain it.

Referring to Bruce Nauman's 'imagined' work *Untitled* (1969),

> '..because we could not see it - we could think about the microphone a mile down into the earth, the simplicity of the idea allows the imagination to make its own picture.' (Kelly, 2011 p.186).

Naumans' work, like the presentation of *You Are Here*, aims to allow the imagination of the visitor to 'make its own picture', and reflects also the ideas of Seth Kim-Cohen where he has discussed how much to spell out to the visitor when introducing an artwork (See Introduction p.13). Connecting with the visitors' imagination by the suggestion of the phrase 'cosmic rays' and 'microphone a mile



Figure 50 – Centaurus A or NGC – 5128. Photo reproduced with kind permission of SSRO - Star Shadows Remote Observatory – South Chile.

down in the earth', illustrates how the visitor can make their own associations with these works.

The journey of the cosmic rays to our ears

To create the installation where signals could be received from space, a collaboration was set up with students at Ilford County High School and their teacher Dr. Paul Edmundson. We met up three times between June 2012 and March 2013. Edmundson was keen to encourage his Year Twelve students to plan and develop systems and equipment independently from their exam curriculum, investigating how art and physics can work together.

The school had Scintillator Detector Boxes that can detect secondary cosmic rays. High up in the earth's atmosphere, cosmic rays interact with atoms and molecules to generate a shower of particles; in this case the muon flux. They are remnants of high-energy particles that start life in 'deep space'. They are in a family of radiating particles and a source of different strands of research (Bryman, 2013).

To find out exactly how far the ultra high-energy cosmic rays that became the muons we were detecting had travelled, Dr Edmundson reported that the research known indicated that:

- There is an outer limit to the distance scientists know ultra high-energy cosmic rays have travelled (JZK limit), because of the way ultra high-energy cosmic rays interact with the Cosmic Microwave Background Radiation (CMBR). The outer distance is 120-160 million light years.

- Because of the information above, the galaxy Centaurus A, (distance of 11million light years) that has an energetic mass (back hole) at its centre, is a 'likely candidate' for ultra high-energy cosmic rays to travel from (Bull, 2011) (See figure 50).

So an approximate distance can be described, and I created a visual representation (See figure 51).

At the school, under the wooden lid of the detector boxes there is a neutral scintillator plastic (Bicron), 60cm x 60cm and 1cm thick. When a charged particle passes through them, the particle loses energy, which is transferred to a photon of blue light. This travels through a Photomultiplier Tube detector (PMT) by a system of internal reflection. The blue light particle or photon is absorbed by an electron in one of the layers of material (caesium nitride) in the PMT. Between the many layers of caesium nitride, each with a large voltage between them, the electrons are accelerated and cascade through, multiplying at each layer till they are strong enough to form a pulse to update a counter that registers in the computer (See figure 52).

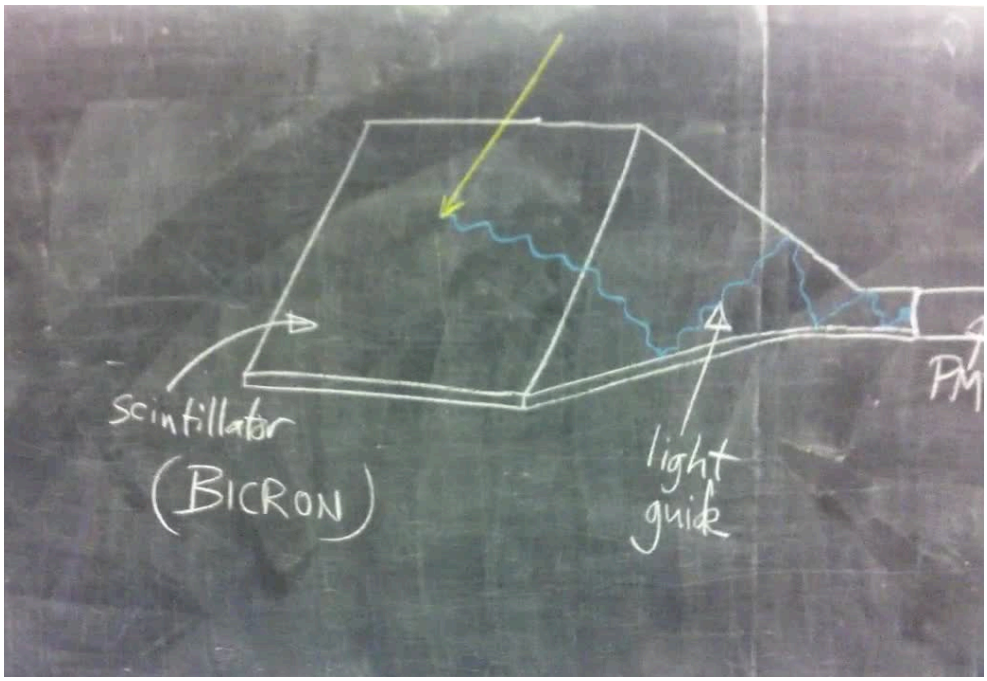


Figure 52 - Detector box diagram

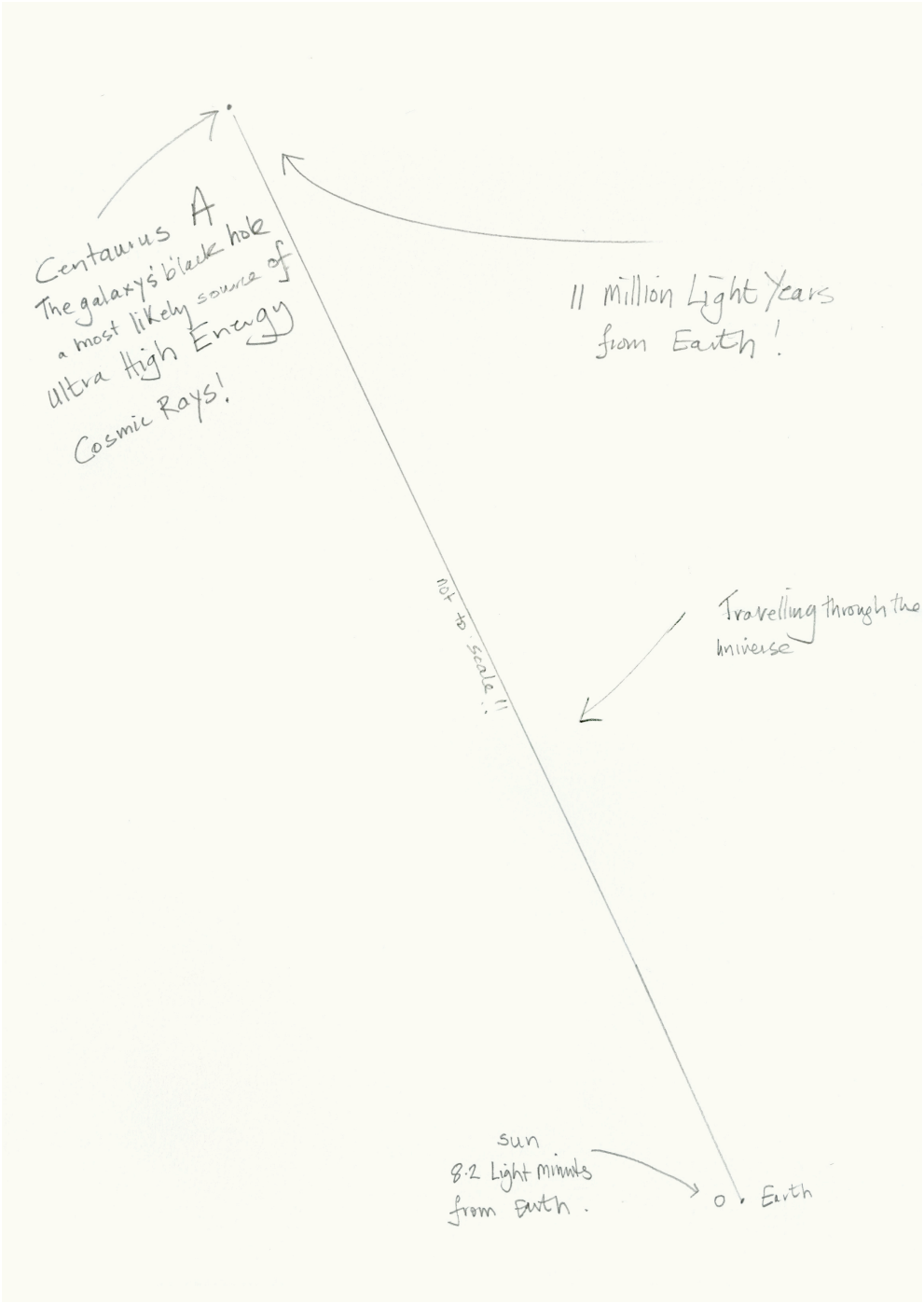


Figure 51 – Distances to Centaurus A

The three boxes, about 10 metres apart, are placed to help calculate the direction the rays are arriving from and whether they are from one or several showers (See figure 53). Dr Edmundson had calculated that this distance would correspond to 120 nanoseconds, and if the boxes are triggered within 120 nanoseconds it's likely the particles are coming from the same shower.

Using formulae to represent the value and character of the detected cosmic rays in relation to their energy, the students wrote their own programs to handle and organize the data, including designing code to represent the values of strength, duration and direction of the cosmic rays hitting the detectors from different parts of the sky. These values would be calculated and interpreted into data that would be streamed to a computer in Bristol that would assign a sound to the data values. There would be three speakers in Bristol that corresponded to the three detector boxes in Ilford (See figures 55, 56 and 57), so sounds could be heard in any of the three speakers in Bristol depending on the direction from which they were received in Ilford (See figure 54). The team leader for the work in Ilford was Vikash Patel.

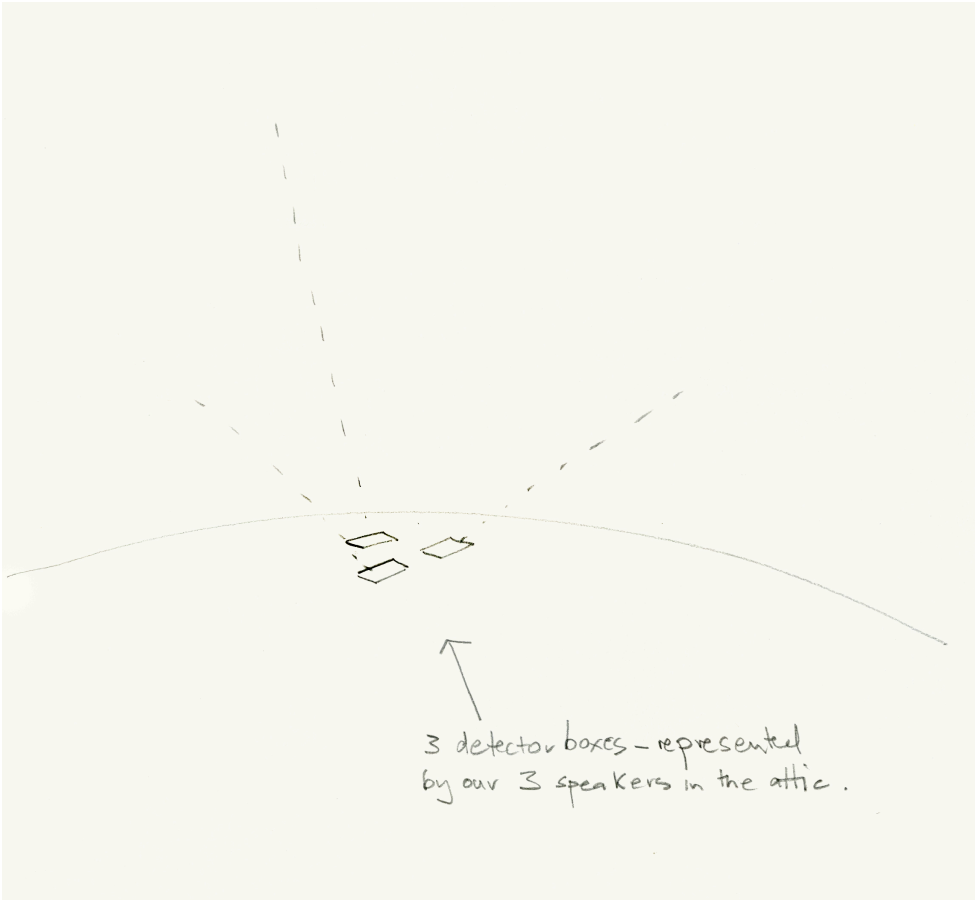


Figure 53 - Muons hitting detector boxes



Figure 54 - Detector Boxes - Ilford



Figure 55, 56, 57 - Speakers with labels

The sonification of cosmic rays

The sonic properties of several of the works in the study have allowed an experience of both sonic and tactile qualities. This work where the signals are assigned a set of sounds, in a software program, poses the possibility that the sonic qualities of the sounds heard are suggesting ideas, conveyed by the sounds, that will help create and map out the geographical ideas of the piece.

Aims and ideas for the installation were discussed with the students along with their plans for working out the values they needed to calculate. Ideas were exchanged about the presentation of the work and the sounds we could create to represent the detected muons. We exchanged sounds available on the software 'Massive', choosing sounds appropriate to the situation in Bristol, where the variation in strength, length and duration of the signal, and the size of the room were all taken into consideration.

Earlier in the process we had decided to sonify the less frequent but stronger low-frequency primary muon rays. This was because the higher energy alpha muon showers gave a clearer indication of the direction they had come from through the atmosphere above the boxes than the more frequent but less energized beta rays. Consequently there was a gap between detected signals; sometimes up to a couple of minutes. I put up a sign that indicated that there might be gaps between the signals in case the visitors thought the equipment had stopped working (See figure 58). I also hoped waiting for the signals would place the visitors in a state of anticipation.

We discussed several options of sending and receiving data from Ilford to Bristol, including using Pure Data, File Transfer Protocol (FTP), Filezilla and Python 3.3. The data received would be played within Ableton by Massive then sent via a sound card (Motu- Ultralite mk3 Hybrid), to the three speakers.

The sound was chosen after many sounds were tried. I found later descriptions of a collaborative process for sonifying particles by Katherine Vogt detailing how complex the decisions are. In her paper she assigns sound to particles by comparing their properties (Vogt, 2010 pp.95 - 96). Interestingly in regards to

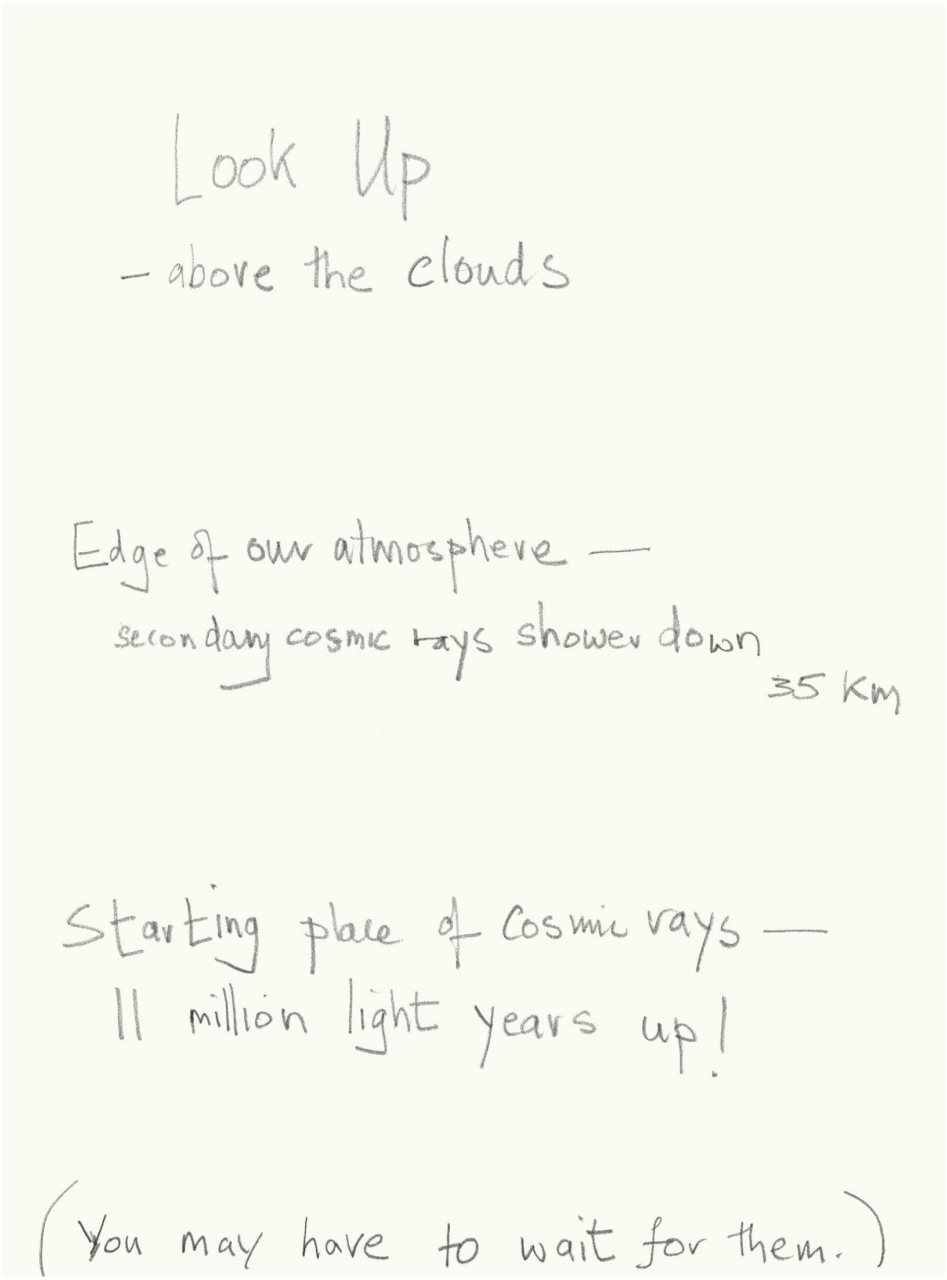


Figure 58 - Signage

sonification decisions, an artwork by Charlie Hooker: *Audio Accompaniment* (2011) uses the keys of a piano to sonify the detected radiated particles. He used a Geiger Counter which differs from the scintillator detectors in this project as a Geiger Counter will also take radiation generated from inside the atmosphere as well as the rays coming from further away in space.

It became evident to me, after auditioning sounds with Patel, that some sounded too composed, some too grand and did not fit the nature of the larger signal trails from muons I had seen in the Cloud Chamber at the Summer Exhibition showing both alpha and beta muons trails. Here are the bigger alpha particles of the muons flux we sonified in the project, shown clearly in the video clip. (YouTube, 2010). After talking with Vikash Patel and Williams, I mentioned in an email that I preferred,

> '…noise that's not complex but interesting, the electronic edge of crackle. I am not keen on the Retro Style Sci Fi , but favour noise-like qualities, with not too much bass as it sounded too 'synthy'.'
> (Email communication to Patel)

I felt that the situation was too complex for the listener to take in regarding understanding where the sound was coming from, so the sound itself needed to be a simple illustration of the nature of the signal I had seen as an image.

Lastly I will comment on the work as a whole; the ubiquitous house and our abilities to imagine further and further out from its familiar walls, roof and floor. The vibration that created a shaking kitchen posed questions about our assumptions that the ground is solid and that there is an 'outside' and an 'inside' to a house when vibration brings in activity from the neighbour's movements up the road and traffic streets away. I was reminded of the work of Gordon Matta-Clerk, *Moment to Moment: Space* (LowdownMagazine.com, 2013), where he allows the onlooker to deconstruct the shape and fabric of 'the house', treating it like a sculpture. He prompts the onlooker to question our assumptions of the 'inside' and 'outside' of the house, showing ultimately that we don't often think of the outside of the house, let alone outside our earth's atmosphere, when we are inside it.



Figure 59 – Looking up

Thinking and looking up and above the house is not a usual activity (See figure 59). John Luther Adams, because of his work with *The Sonic Geography of Alaska* working with signals from outside the earth's atmosphere, describes,

> 'Sound is a way of touching at a distance'
> (Adams, 2011)

I found this an appropriate phrase considering the mixing of sonic and tactile senses throughout the ideas in *You Are Here*. Pauline Oliveros describes how our perception of these properties of sound can affect us and connect us physically to our surroundings,

> 'As I lean on my table my arm receives sympathetic vibrations from the low frequencies of the bulldozer, but hearing seems to take place in my stomach. A jet passes over. Some of its sound moves through my jawbone and out the back of my neck. It is dragging the earth with it.'
> Pauline Oliveros. (Oliveros in Cox, 2006 pp.102 - 103)

In *You Are Here* the visitors had the experience of listening to both extended distances articulated by sound arriving from seismic activity on other continents; cosmic rays from space and the sound of their own heartbeat. Visitors were invited to connect these activities. Placing ourselves as not only the observer or listener, but the object of the work: the body into which we are listening, puts us (the source of the heartbeat sound) in direct relation to the other heard locations of the work in *You Are Here* i.e. the extreme depths of the earth and from outside our galaxy, pointing out an inextricable connection.

Conclusion

Throughout the study I have been examining the following questions,

1. How does our experience of sound change in relation to the materials through which it is transmitted?

2. How do listeners develop an understanding of the transit of sound from source to perception?

3. How can the physical properties of sound become manifest through the production of Sound Artworks?

4. What is the existing context in Sound Art Practice for the study of Sonic Phenomena?

In the first question, ' *how does our experience of sound change in relation to the material through which it is transmitted?',* our experience of sound does change in this situation, and to illustrate this I will identify instances where this occurs in the study.

The work *Ground Sound* and the work *You Are Here,* demonstrated that the speed of sound if it travels through the ground is different from the speed of sound if it travels through the air, (See Introduction p.11). Visitors were able to experience the time discrepancy between action and sound and commented:

> 'It paces time differently...'
> 'Intense – don't really know what's going on.' (*Ground Sound* p.22)

In a similar way I compared sound heard through water and air in *Through the Bath Water* (p.48), and commented,

> 'The source of the sound from under the water to my ears (underwater) travelled differently, seemingly filtering out some sound frequencies and accentuating others.'

The sound experienced through the body in the works *Through You*, and later *You Are Here*, illustrates specifically that as one of the materials through which sound passes, the listener or 'body', is part of that connecting system.

> '…I am but an organism of skin, bone and fluid, capable of conducting sound; putting 'me' in the same category as the other materials I have been considering in this study.'(*Through You* p.60)

As sounds change when passing through different mediums, our experience of them (as compared to the normally anticipated sounds we expect when they pass through air) is different, and our focus is brought to bear on the fabric, substance and density of those materials. In relation to this question, the findings in the study point to the connection that this change of sound experience brings to the listener with their material and physical surroundings, putting them not only 'in the same category' as the materials considered but inextricably connected.

> 'Placing ourselves as not only the observer or listener, but the object of the work: the body into which we are listening…' (*You Are Here* p.108)

In conclusion I found experiencing the elemental nature: the vibrating particles of sound passing particularly through me, has allowed me whilst making these works, to rethink my connection, via the laws of physics, to the physical universe we inhabit.

I will describe next a response to the second question, *'how do listeners develop an understanding of the transit of sound from source to perception?'*. My relationship with this question started early in the study when I thought about seismic sounds, described in the Introduction (p.11), and the challenge to think about long distance sound waves. My research then extended to signals outside the earth's atmosphere (p.16).

The 'journeys' mentioned in the following paragraphs, have in common the fact that our perception of them starts from places we can't see but are required to imagine. When making the work *Ground Sound,* where I was interested to show how far sounds had travelled through the earth, I asked the question,

> 'Can we map geographical spaces in our imagination from our understanding of sound?' (*Ground Sound* p.31)

I wrote about the kitchen in the *You Are Here* house,

> '…I wanted to create a situation where the visitor would think of places suggested by these sounds they heard, deep within the geological strata below the city…'
> (*You Are Here* p.83)

In the commentary, the scale of distances focused on in the work *You Are Here* (p.105) particularly the distances from out side the earth's atmosphere, are described thus,

> 'Look up - above the clouds,
> Edge of our atmosphere - secondary cosmic rays shower down 35kms,
> Starting place of cosmic rays – 11 million light years up!'

A visitor interpreted the ideas of extreme distances in relation to themselves commenting,

> 'I loved that you could listen to your own heartbeat, as if to reassure yourself that although you are tiny compared to the other things you are listening to, you are there and alive in all of this vastness of earth and space.'
> (*You Are Here* p.89)

These ideas indicate that imaginative engagement of the visitors with the works is key in response to the question of how they develop an understanding of the transit of sound. In response to the question '*how do listeners develop an understanding…',* I describe how the idea of the 'context' of an artwork is important, and comment,

> 'Kim-Cohen describes the sound in its context giving ' possibility to meaning', rather than being told directly…decisions were made to present the works in different ways to bring about possible individual associations for each visitor to the work and provide a 'context'.' (Introduction (p.13)

New territories of thought were opened up after thinking of the journeys of sounds from source to perception involving the idea that signals go through transition (from one type to another) before arriving at our ears as sound. When the source of

these signals start as types we are not able to hear or sense without technical equipment, I commented in *You Are Here* (p.91) that,

> '….. it is evolutionary happenstance that our human ears, and senses, work in the way they do, and creatures that happen to have evolved differently from us are able to detect signals on the electromagnetic spectrum,'

The idea that there are sounds and signals we can't access, but are there as a family of signals is identified by Pauline Oliveros as the 'Sonosphere.'(Introduction p.15). Further to this idea, Salome Voegelin describes that those sounds not heard by our ears could be classed as 'yet to be imagined'. These ideas broaden the response to this question via the works produced in this study, extending further the geographical space imagined by the visitor to the works. To conclude I note that the de-compartmentalisation of the families of signals (discussed above) has allowed me to re-scale and expand my own horizons, 'feeling in touch' with places and thinking about ideas via sound and my own imagination, I'd not previously thought I could be connected to.

The third question states*, how can the physical properties of sound become manifest through the production of Sound Artworks?* In describing *You Are Here* (Chapter Five), I was able to emphasize that my methodology in the study has been concerned with finding out what equipment is suitable to enable the artwork, working with the properties of the sound and making the ideas operational. The status of the equipment throughout the work therefore can be described as

'…defining the practice in the study.'(Chapter Five p.80).

Further to that and in response to the question, I will identify in the commentary instances where the way the physical properties of sound can shape thought, extend our imagination and expand the scope of the ideas that sounds suggest to us. Common to the three instances commented on from the works in the study and quoted below, is the key idea that the artworks encourage the mixing of senses. Firstly, responding to the question, some works created a mixture of sonic and tactile experiences. Visitors commented on the transducer placed on their hand and the vibrating kitchen, where they experienced the feeling of the vibration of a sound they could also hear.

> ‘Mixes sound and touch – like a little hamster vibrating in your hand.’ (*Through You* p.61)

> ‘…you can see it palpitating. ...I had to touch it to understand what’s going on, in order to understand why my eyes are seeing the whole kitchen moving.’
> (*You Are Here* p.83)

Secondly, expanding the scope of the works’ ideas and creating an idea in the imagination of the visitor after experiencing the work *Ground Sound* (Chapter One*)*, a visitor commented on a sound they could not hear, but could only imagine.

> ‘Is there just a massive sound that is inaudible to us beneath our feet?’ (*Ground Sound* p.24)

and responding to the question posed in that chapter ‘Can we map ideas from an inaudible sound experience or a suggested sound idea?’

Thirdly, a multi – sensory experience incorporating sound, vision and ‘felt’ vibration resulted in a visitor commenting,

> ‘I felt that the way the sound came to me in the heart room, it was a very physical sound. I could make a drawing from that sound. I got a very clear idea - a bit like getting a sonar scan – it’s like 3D imaging but sound.*’* (*You Are Here* p.86)

Lastly the territory opening up around the perception of the mixing of senses and the observation of how we listen, is referred to in the Introduction (p.16), when Saunders writes about Oliveros,

> ‘…she encourages the participant to observe <u>themselves</u> and how they are thinking of sound. …she heightens our perception of the different ways we receive sound.’

As an example of what Steven Connor terms,

> ‘… a disruption to the usual habit of listening,’(*Through You* p.64)

the visitor, listening to sound heard from the 'inside of their ears' (*Through You* p.59), finds that the disrupted listening experience causes them to focus on and question the sonic information they are receiving. Emphasising here that sound is describing space, they question the workings of their own imagination,

> 'When you put it (sound) into your body you start to feel more mechanical about it – is it 'spatial out' or 'spatial in?' (*Through You* p.63)

In conclusion to this question I'd say that the versatility of the imagination in conjunction with sound has surprised me. It has opened the door for the possibilities of observing and experiencing the understanding of our world though the synchronicity of our senses.

In response to the fourth question, *'what is the existing context in Sound Art Practice for the study of Sonic Phenomena?'* the commentary refers to other Sound Art Practitioners, where their work and ideas have been referred to, and where comparisons have been made in relation to the works of this study. The artists and writers who have particularly encouraged me to develop ideas as the process of the study has unfolded, are mentioned in this conclusion, namely: Seth Kim-Cohen, Brandon LaBelle, Steven Connor, Salome Voegelin, Douglas Kahn and Pauline Oliveros.

Concepts explored in this study may lead on to further projects employing similar methodologies to explore the fundamental nature of our physical environment investigated by sound in conjunction with the idea that the visitors' actions and imaginations are central to their understanding of the work. As part of my methodology, feedback from the visitors importantly guided and informed my processes. In Chapter Four (p.65), for instance it,

> '..inspired me to be more challenging etc....'

Finally, the contribution the study makes in the field of Sound Art and Soundscape Studies as stated in *You Are Here* (p.66) is about the new understanding of the visitor as they experience the sound artworks in a setting and context that is well known to them.

‘The familiar context for the work, a house, created the potential for the visitor to go back to their own house and to think about their own house in a different way…Stepping back into their own kitchen, boxroom or attic, they would think of these places from a different perspective. The work would create for the visitor, a new knowledge, a new understanding of their place, their home, in the ‘Sonosphere’ of the sounding universe.’

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