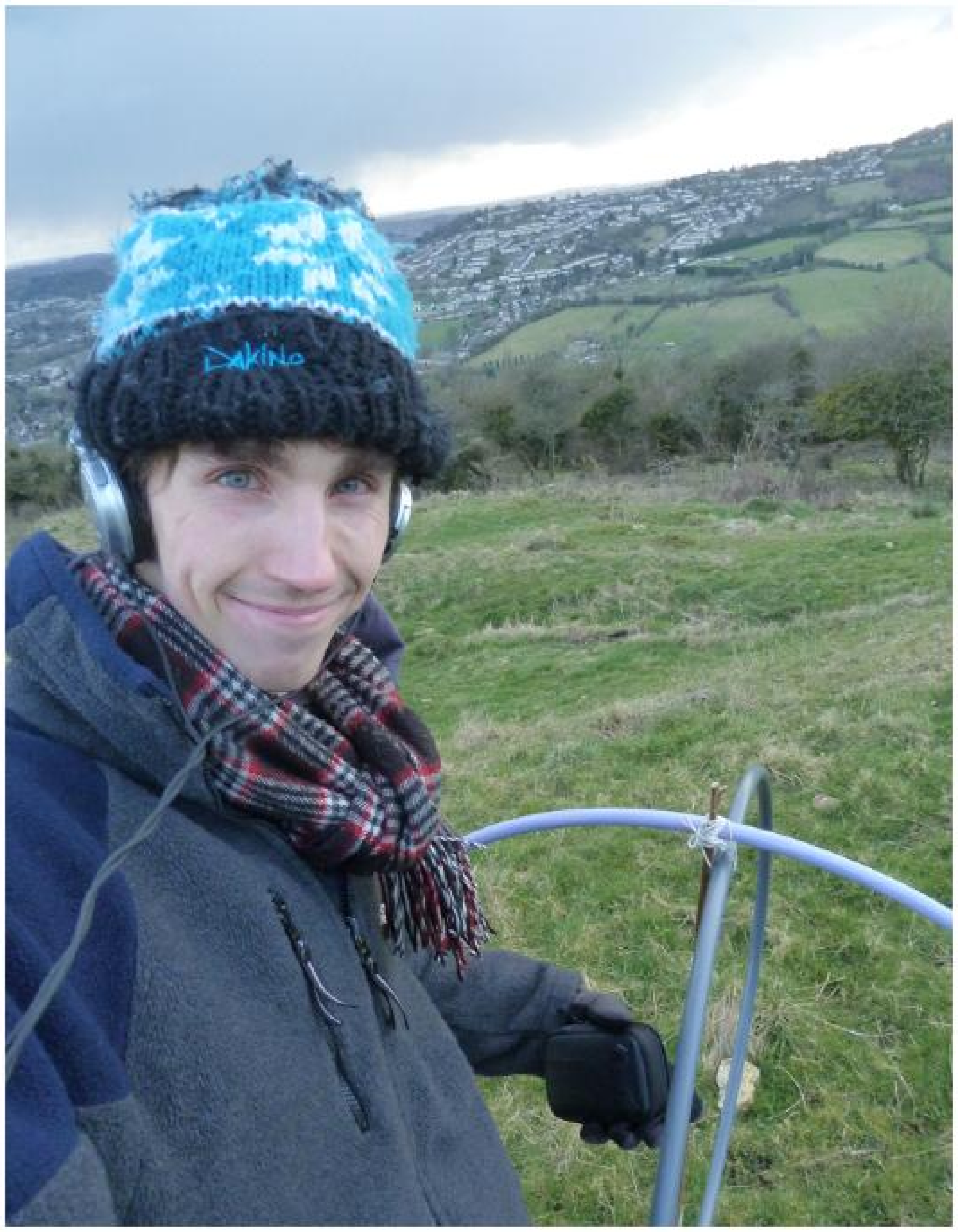
V L F

A SOUND ARTIST'S GUIDE

by Dan Tapper

INTRODUCTION

Welcome to the second edition of ***VLF: A Sound Artist's Guide***. Over the last two years my practice has evolved, expanding how I work with Very Low Frequency (VLF) and sound in general. This new edition builds upon the first to give an updated and more in depth overview of how to get started with listening to VLF sound as well as recording and using it in an artistic context.



My name is Dan Tapper. I am a sound artist and composer. I became very interested in recording and using VLF signals in my work three years ago. Since then I have used VLF in a variety of ways: large scale installations in a Machine to Listen to the Sky, broadcast works such as Recording the Spirit Level, video work with Changing Signals, alongside building a number of devices and gathering field recordings.

To me VLF is important because it reveals a rich area of sound that is hidden to us without the use of special equipment. These sounds include naturally produced radio signals (lightning, sunspots, northern lights, etc.) and also manmade ones (radio transmission, mobile phone signals, etc.). By listening to VLF, we are tuning into the pulse of nature and hearing how pervasive our manmade electromagnetic emissions are. It can be scary, humbling and beautiful to hear this sonic interplay.

The purpose of this manual is to show people how to listen to VLF. I want to share these sounds, which can be revealed using some very simple DIY technology. VLF isn't just important for sound artists and scientists; it's important for everyone – it's a way to explore our universe through sound and experience our world in a different way.

Everything you need to begin listening to VLF is discussed within this manual, alongside some more creative and artistic uses of recorded signals.

I hope you enjoy listening to the sky!

WHAT IS VLF?

VLF is a radio spectrum ranging from 3kHz to 30kHz. This is mostly below the range of manmade radio broadcasts. The signals in this band are produced naturally by the earth's ionosphere and include lightning strikes and the northern lights.

Technology also emits signals that fall into the VLF range. An example of this is a low constant hum at around 50hz[1]; this is produced by the power grid and becomes quieter or louder depending how near you are to a mains power source.

How do you listen to VLF?
We listen to VLF through devices known as inductors. These are large loops of wire that respond to magnetic fluctuations. When the output is connected to an audio device, these signals can be heard as audio and also recorded.

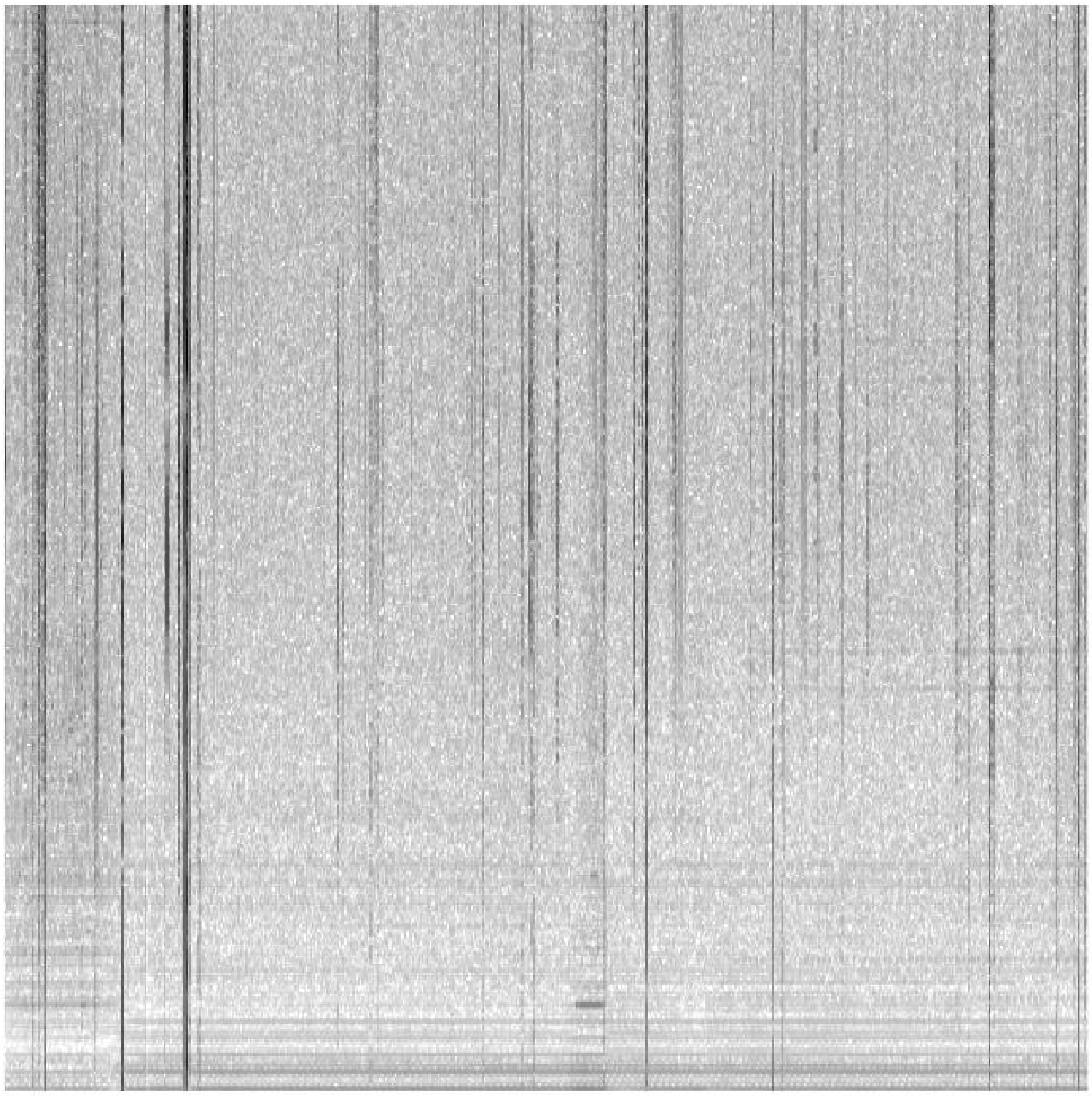
VLF is used in the scientific community to monitor space weather. For a sound artist, the ability to hear a spectrum of sound inaudible to human ears is very exciting and opens up a whole new world of artistic exploration and possibility.

1. Some power grids, such as those of the United States, produce a higher range 60hz hum.

My VLF gear, on a recent recording expedition to the Black Mountains, Wales.

WHAT YOU SHOULD

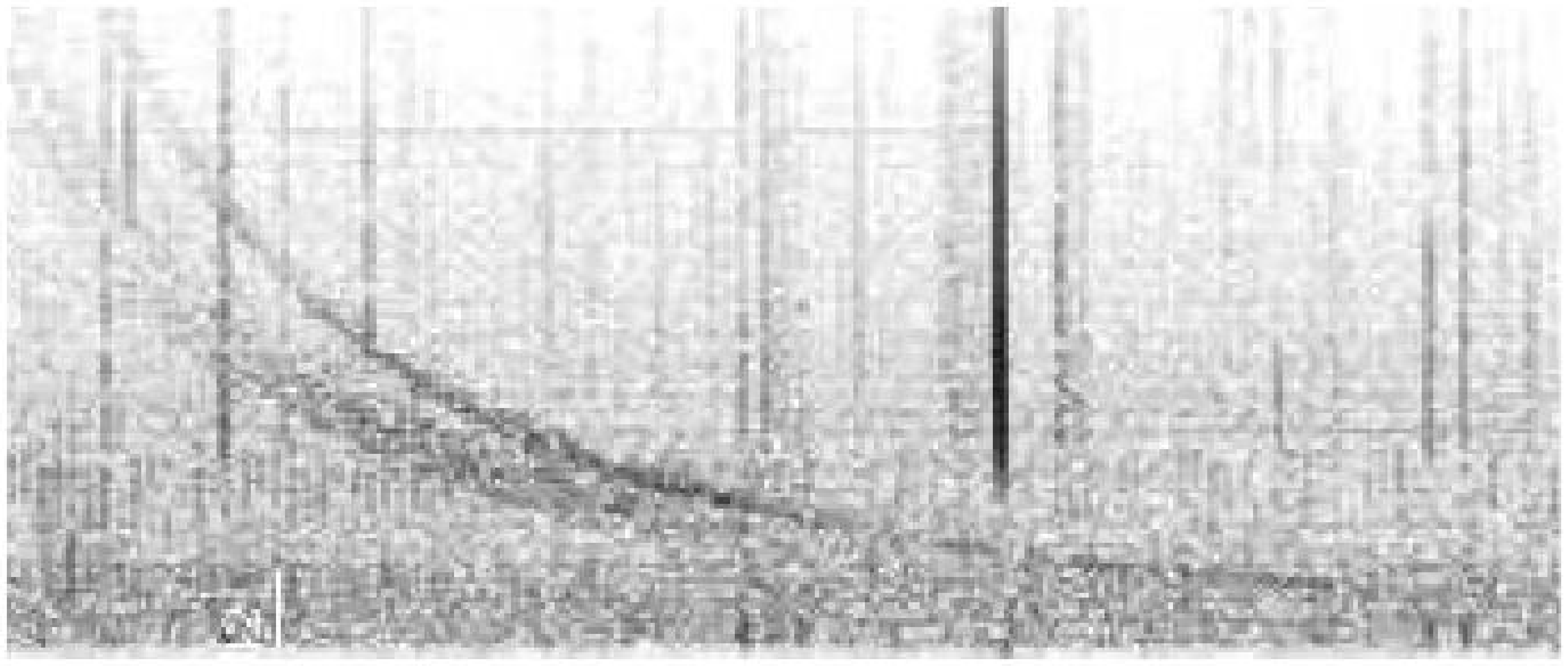
Sferics:
These are atmospheric disturbances caused by lightning. These signals can be picked up from thousands of miles away and manifest themselves as short, sharp clicks. These are one of the more common sounds to hear whilst listening to VLF.



A spectrogram showing sferics.

Tweeks:
These are produced through similar disturbances to sferics. The difference in sound comes from the source travelling a larger distance through the ionosphere, resulting in lower frequencies travelling slower than higher ones. Rather than short, sharp clicks, tweeks sound like birds tweeting. A visible hook often appears on sonograms indicating tweeks.

Whistlers:
Like sferics and tweeks, whistlers are produced by atmospheric disturbances caused by lightning. The sounds are more dispersed than tweeks, travelling greater distances through the ionosphere and creating a high to low frequency whistle that lasts around a second.



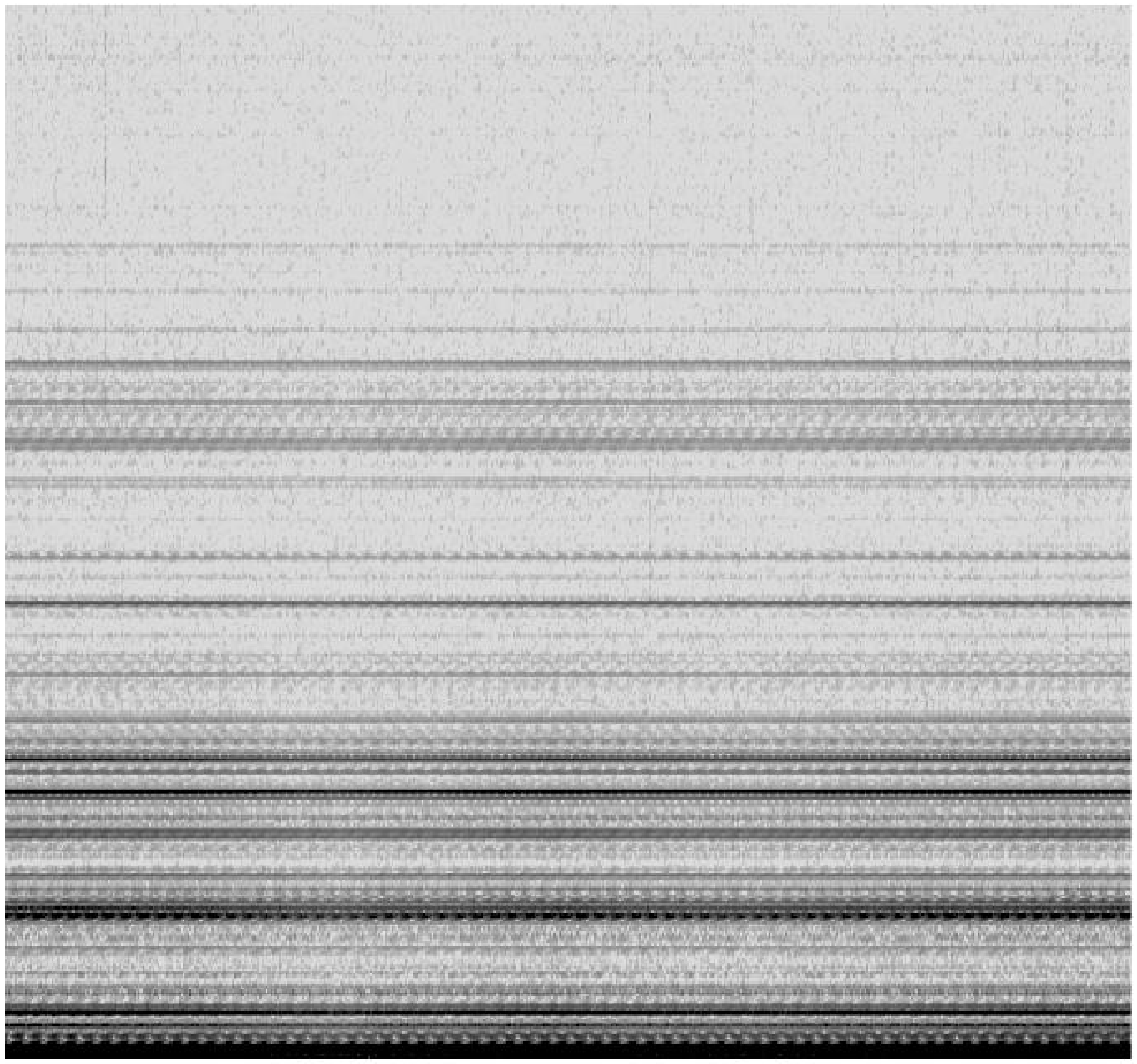
A spectrogram showing a whistler.
Image from Backyard Astronomy.

EXPECT TO HEAR

Northern Lights:
If you're able to get far north (where reception is best) and away from large areas of manmade electrical signals, you may be able to pick up VLF signals produced from the Aurora Borealis. This sounds like large numbers of birds flocking and calling to each other.

Manmade Interference:
A number of manmade signals can also be heard in the VLF band. A prominent sound is often from the electrical grid – a constant low hum at around 50Hz. Mobile phone signals, satellite communications and some military communications can also be heard.

Northern lights in Manitoba, Canada.
Image from Stephen P. McGreevy.



A spectrogram of the 50Hz hum.

SPACE SOUNDS

Scientists have used large radio antennas to gather information about space since the 1930s. The first discovery that radio waves propagated in space came from Karl Jansky from observations of radio emissions from the Milky Way galaxy. These radio telescopes are often built using similar concepts to VLF receivers. They achieve higher rates of accuracy and sensitivity by increasing the size, scale and number of the receivers used.

An example of one large-scale radio astronomy operation is the Low-Frequency Array (LOFAR) based in the Netherlands. LOFAR uses about 25,000 small antennas, which are combined in a number of larger stations. Combining these antennas in different configurations controlled via a computer allows for different areas of the sky to be monitored. Other radio astronomy facilities often use large parabolic dishes rather than the omnidirectional antennas used in LOFAR.

A small number of LOFAR's antenna.
Image from Tammo Jan Dijkema

The data recorded by radio telescope arrays is huge and requires powerful computer systems to process. The data is often viewed visually and sometimes sonified.

There are a small number of artists who have collaborated with radio astronomers to create pieces that present or repurpose the scientific data.

Notable artists in this area include Semiconductor, who worked with data gathered by the Canadian Array for Realtime Investigations of Magnetic Activity (CARISMA) in their piece 20Hz, and r a d i o q u a l i a who have created Radio Astronomy installations.

If you are interested in exploring data from a radio telescope, you can access CARISMA's publicly available data *here*.

You can learn more about the History of the Universe in Sound in this excellent talk by Honor Harger, gallery curator and cofounder of r a d i o q u a l i a.

Four antennas of the Atacama Large Millimeter Array (ALMA).
image from European Southern Observatory (ESO)

HOW TO LISTEN TO VLF:

Materials:

- Frame – My receiver is made from a hula-hoop but you can use anything you want.
- Copper wire
- Electrical tape or some kind of insulating material
- Unbalanced jack plug – This allows you to listen to the output of your receiver; it's your choice what size/kind of plug you use. I'm using a 1/4" TS jack.
- Solder
- Soldering iron

1. Find and measure your frame.

For my receiver frame I am using a hula-hoop with a diameter of 0.8 meters. I cut the hoop with a pair of scissors leaving a hollow circular tube, through which I am able to thread my wire. Other possible frames include large wooden crosses made by nailing two pieces of wood together, bicycle wheels, found objects such as the base of a Christmas tree or even having no frame at all and securing the loop using cable ties.

2. Calculating wire.

Once you have a suitable frame and measured the diameter you are able to begin calculating the amount of wire needed for your receiver.

To determine this, there is a simple rule of thumb stated in the book Radio Nature written by Renato Romero. This tells us that to pick up VLF signals, the receiver needs to have an effective area of 12 square meters.

To work out the area circumscribed by the receiver we use the equation πr^2:

$\pi = 3.142$
$r = 0.4$ (the radius of our receiver – half the diameter)
$r^2 = 0.4 \times 0.4 = 0.16$
$r^2 = 0.16 \times \pi = 0.5$ square metres – this is the area that our loop circumscribes.

Once you have worked out the area your loop circumscribes you can determine how much wire is needed for your loop.

Do this by multiplying the number of turns by the circumscribed area. For example, my loop is 0.5 square meters so 28 turns is equal to 14 square metres.

$28 \times 0.5 = 14$ square metres

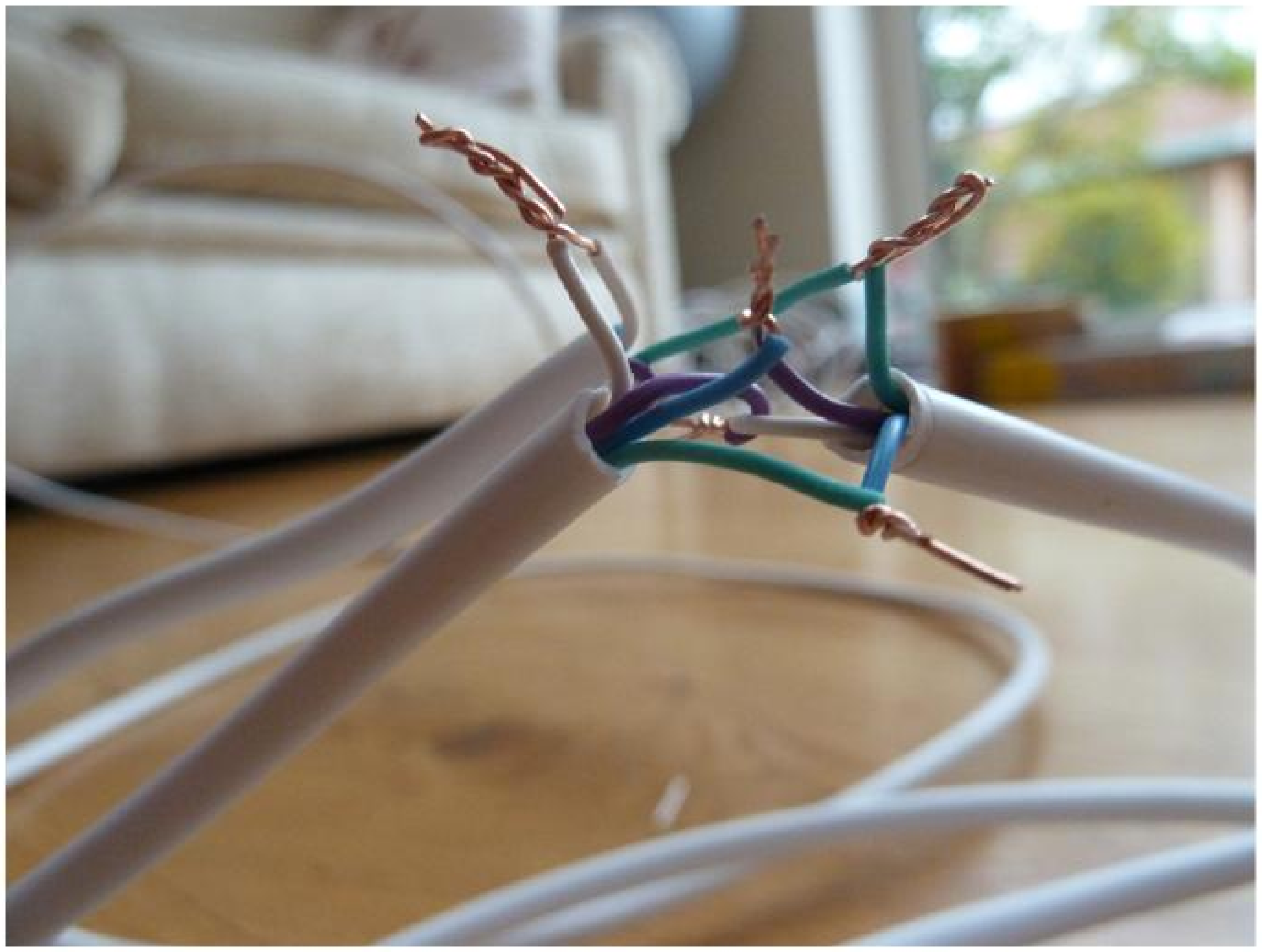
A DIY RECEIVER

3. Wrapping the wire.
Wrap the wire around your frame however many times you have calculated – e.g., 28. Once you have finished you should have two ends of wire (the beginning and end of the loop). If the wire is slightly loose around the frame secure it with cable ties or electrical tape to keep it in place.

Note on the wire
Rather than using a single continuous length of wire, I am using four-core signal cable. This means that I have to connect the wire in series to create the continuous loop of wire required for a VLF receiver. Using wire with multiple cores allows me to quickly create a large number of turns within my receiver frame; I have partly used this method because of the space constraints of the interior to the hula-hoop. When making receivers where the wire is wrapped externally, I prefer to use continuous lengths of magnet wire – I mention this so as to explain that you can tailor how you loop your wire to your frame.

4. Listen to the loop.
Once you have looped your wire it is a good idea to test out the receiver. You can do this by gently connecting your output wires (the two ends of wire) to a jack plug and listening through a battery-powered amplifier. If the loop is working and picking up signal you can

Wrapping the wire.



Connecting in series.

begin to solder up your receiver. Once you've finished soldering, make sure to cover any loose or uncovered wires with electrical tape or some sort of insulating material. This stops the wires rubbing together and should protect your receiver from the wind and rain when recording outdoors.

You are now ready to go out and listen to the electromagnetic spectrum!

Tip

Try testing the receiver out by listening to electrical appliances around the house such as computers, television, microwaves and radio. These produce strong electromagnetic signals, which can easily be picked up and determine whether the receiver is working.

Further stuff:

If you will be using the receiver a lot outdoors, it might be useful to make a handle. I made a handle by securing a thin piece of wood to my receivers. This allows me to hold the receiver high above my head like an aerial and also stake it into the ground. It is also a good idea to have some sort of extension cable for the receiver's output (especially if the original output cable isn't very long). At close range audio recorders can create audible noise in the VLF band so moving the recorder further away can help to clear up your recordings.

Two VLF receivers made from four-core signal cable and hula-hoops, with makeshift handle. made by Dan Tapper in Bath, UK.

VLF Receiver made from eight-core signal cable and secured with cable ties by composer and media artist Thomas Rex Beverly, Ohio, USA

VLF receiver made from magnet wire and found wood. Made by Dan Tapper in Toronto, Canada

VLF receiver made from magnet wire and tree branches by sound artist Claude Wittman, Toronto, Canada

TOOLS OF THE TRADE:

In this section I'm going to look at one of the simplest ways of listening to VLF signals by directly plugging the output of a receiver into an audio recorder. There are a number of cheaply available devices that allow us to quickly listen to and record VLF signals. There are several things to consider when looking at audio recording equipment.

Inputs – Make sure your receiver's output jack is compatible with the recorder. Many low-end recorders have limited inputs, which only accept 1/8" jacks. If this is the case tailor your receiver's output to the recorder.

It is also important to think about how many inputs you need. One is fine if you are content recording a single receiver but if you wish to expand your setup, a single input recorder may limit you. Other considerations should be about if you wish to use the recorder to record sounds outside of VLF. If this is the case you should think about what sorts of sounds you wish to record, the quality of the inbuilt mics and if you are able to connect and power microphones with XLR outputs.

Pre-amplification – The VLF signals coming straight from your inductor loop will often be very quiet. It is important to amplify these signals in the cleanest possible way, retaining a high quality recording with no distortion. Audio recording devices amplify the signals to some extent; this varies from recorder to recorder depending on the quality of the pre-amp. VLF enthusiasts often build their own pre-amplification devices to amplify signals whilst also filtering out unwanted areas of the spectrum so as to be more attuned to natural radio. From my experience I have found that building a successful pre-amp is quite a difficult task. It resulted with a louder overall signal but noise and distortion were also introduced resulting in dirtier recordings. From a process of trial and error I have found that twinning an audio recorder with a FiiO E06 headphone amplifier made it easier to cleanly monitor my recordings. I later digitally amplify recordings on a computer.

Zoom H1 – £70, €98, $110
The Zoom H1 is a small pocket device available for under £100. It is compact and powered from one AA battery. It features two inbuilt microphones placed in an XY pattern. The device has a single 1/8" mic/line in input. The device is often used as a microphone preamp

for video cameras by budget filmmakers to increase audio quality. For the size and price this recorder is a great buy, allowing you to get started with listening to VLF signals as well as having a pocket-sized multipurpose audio recorder.

Olympus LS-11 – £141, €198, $221

The Olympus LS-11 is a popular low budget handheld recorder. It is larger than the Zoom H1 and powered from two AA batteries. It features two inbuilt microphones, a 1/8" microphone input and a 1/8" line in input. The device has quite low mic/line in input sensitivity and also has a built-in bass roll off, reducing low end frequencies. This feature is not ideal for recording VLF signals; the device's preamps can be boosted by using an external preamp but this adds extra cost and increases the bulk of what essentially is meant to be a handy pocket device.

Zoom H4N – £177, €248, $277

The Zoom H4N is a larger device than the H1 and LS-11. It is powered from two AA batteries. It features two built in adjustable microphones and two XLR and 1/4" jack inputs. It has a number of features not available in the previous two recorders including the ability to record four channels of simultaneous sound – two channels from the XLR and 1/4" jack inputs and two from the inbuilt microphones. This is not especially useful for recording VLF signals but could be used for recording a pair of inductors alongside the acoustic ambience.

Other useful features include the ability to take a mono input and monitor/record in two channels by doubling the signal. The Zoom H4N has a very high input and output gain, meaning that you can record and monitor your signals at high level. This is useful for VLF signals which can often come into the recorder at quite low level. This high level of amplification can result in some noise added to the recording from the preamps. I find the best way is to record at a mid range level and later amplify digitally. The Zoom H4N is a really great way to get started listening to VLF. The slightly noisy preamps are a bit of a downside but overall the device allows you to pick up lots of clear sound from a variety of sources – I've found it to be specifically good at picking up snatches of radio transmission.

Olympus LS-100 – £246, €344, $385

The Olympus LS-100 is a slightly higher end recorder than the previous models mentioned. It is similar in size to the Zoom H4N. Unlike the other three recorders the LS-100 is powered by a lithium ion battery. This gives a longer battery life and is rechargeable. It features two built in high quality microphones, two XLR and 1/4" jack inputs and 1/8" mic/line in input. Like the H4N the LS-100 has a number of extra features, including a built in multi-track recorder, metronome and tuner. None of these are especially useful but expand the recorder's uses outside of VLF and field recording. The device has very high quality preamps for the price and size, resulting in clean recordings; however, the volume of low-level signals can sometimes be quite quiet. The built in headphone amplifier does not allow for signals to be monitored at a particularly high level so when recording VLF signals I often attach a FiiO E06 headphone amplifier to boost my monitoring signal. I later amplify the recordings digitally.

The LS-100 is a really great recorder for general field recording but I don't feel it is particularly effective for recording VLF signals. The device also has some annoying factory settings such as beeping buttons and a speaking menu. These can be turned off but it takes a little bit of time to tailor the device to your method of recording.

My Reccomendation

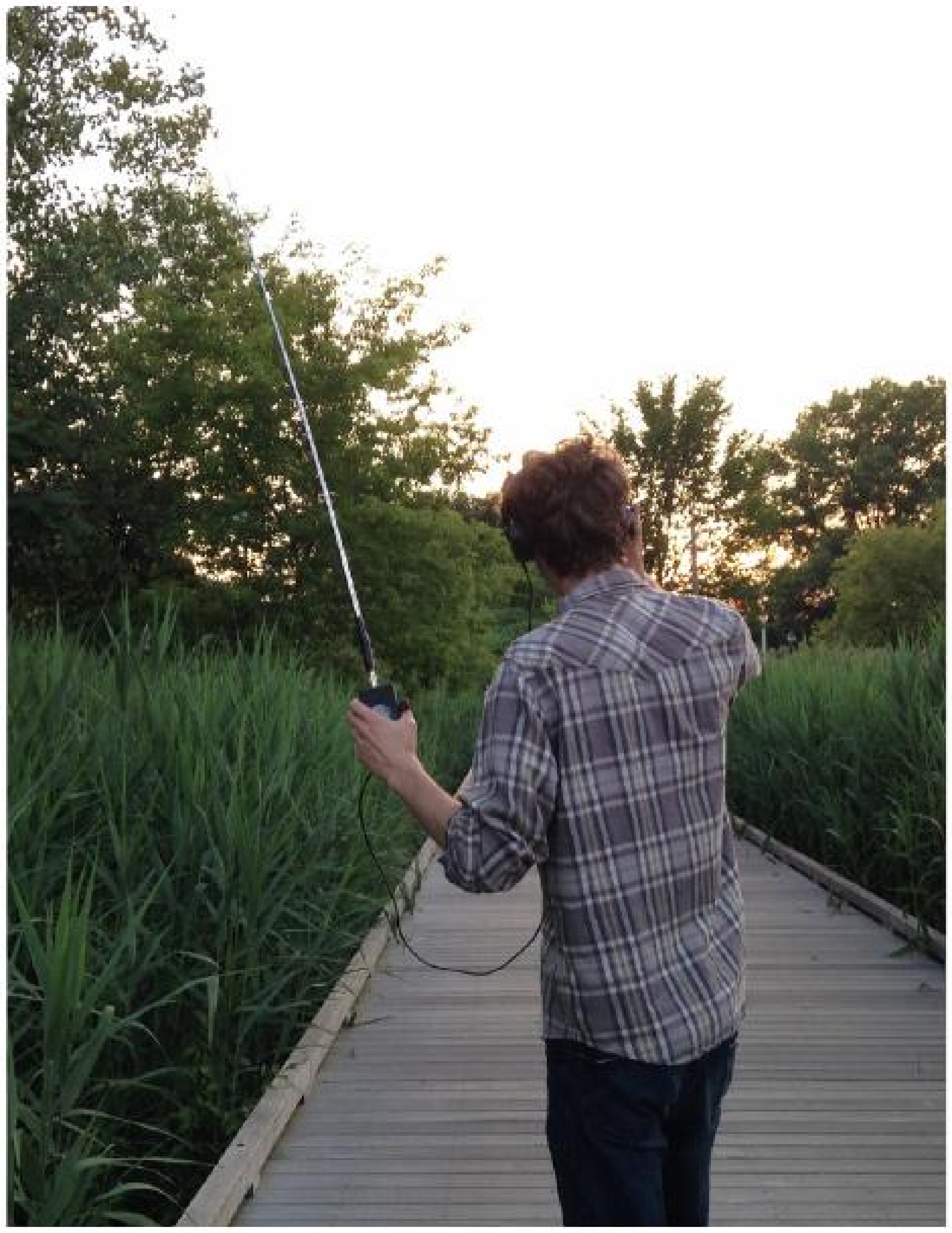
My recommendation for a budget recorder to listen to VLF would be the Zoom H1 as it is portable, requires only a single AA battery and is very affordable with a decent preamp.

My recommendation for a slightly more advanced recorder with more mileage in terms of listening to VLF and field recording in general would be the Zoom H4N. It is well priced, allows a lot of gain on recording and monitoring signals and has a simple and fairly intuitive menu interface.

WR-3 REVIEW

£86, €121, $135 + postage

The WR-3 VLF receiver is a popular hand-held VLF receiver made by Stephen P. McGreevy who has been working with VLF since 1989. The WR-3 has been produced since 1991 and is designed for listening to natural radio signals between 50Hz and 14Khz. It is powered by a 9 volt battery that powers the device for about 20 hours. It also has inbuilt pre-amplification which means you can listen to the signals coming in at high level.



The WR-3 is an electrostatic receiver, which operates slightly differently to the large loop receivers mainly mentioned in the guide. Electrostatic receivers pick up the voltage or current of a signal, whereas the loop receivers pick up the magnetic influence of a signal.

I tested the WR-3 over a period of several days. I was able to pick up very strong sferics almost immediately. I found that areas far away from power lines, with less cover from trees which tend to weaken the device's sensitivity, were the most effective for picking up natural radio. The device is famed for being great at picking up whistlers so I look forward to picking some up in future recordings.

The WR-3 operates as a standalone device – just plug in some headphones and listen – or can be connected to a recording device. I found the WR-3 to be sensitive to the sound of my recorder's internal electrics, partly as I had a very short audio cable. To resolve this issue I think a cable of several feet or more would be of benefit so as to isolate the recorder (on the floor or in a backpack) away from the receiver. I was able to get clean recordings with some manoeuvring directing the audio recorder away from the receiver.

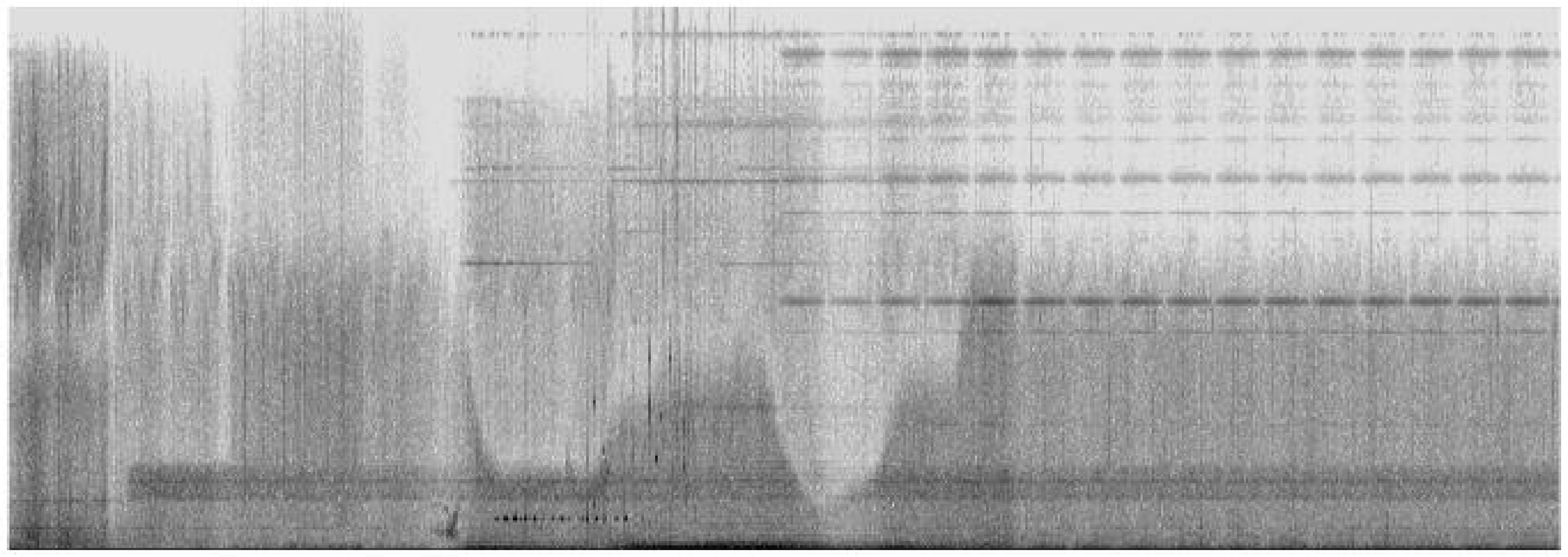
It's been great to finally test out a WR-3 after hearing about it for so long. It's a really effective VLF receiver especially for listening to natural radio and the compact size is very useful for travelling or as a portable recording setup.

You can purchase the WR-3 *here*.

The VLF signals recorded by our simple loop receivers can contain a great deal of sound, from the hum of the electric grid, to satellite transmission, radio signals and natural radio. It is important to develop methods of listening to and processing VLF recordings so as to reveal the areas of sound you are most interested in.

Visual Analysis:
Viewing recordings as spectrograms – A visual representation of the frequencies found in a sound recording can be an effective way of quickly isolating interesting sonic content. Sferics, tweeks and whistlers have distinct sonic characteristics that we can see. Likewise the 50Hz hum and its overtones are easy to isolate visually. There are a number of programs that allow you to view recordings as spectrograms.

Audacity is a piece of open source sound editing software with an effective spectrogram view option. Available for Mac, PC, Linux and Unix.



Audacity's spectrogram view.

Spek is a free spectrum analyser that produces static spectrograms of a sound file. Available for Mac, PC, Unix

Spectrumlab is a free real-time spectrogram and audio analysis tool. Recommended on vlf.it. Available on PC.

My Reccomendation
Audacity is a great place to get started as it works cross platform and is easy to use. It also has a number of useful editing and audio processing features that allow us to effectively clean and creatively manipulate VLF and other audio recordings.

Filtering and Isolating Signals:
A quick and simple solution is to use a banded EQ to amplify and cut areas of signal, revealing the portions of the recording you want. This may not always be the most effective way to filter recordings depending on how much unwanted noise there is in the sound file. A slightly more advanced and effective method is to use phase inversion. To do this copy your audio file to a separate channel so you have two iterations of the same audio file in phase with each other. Invert the phase of the audio copy. This will result in the two files completely cancelling each other out. Load an EQ plugin on the second channel and boost the areas of the spectrum

ISOLATING SIGNALS

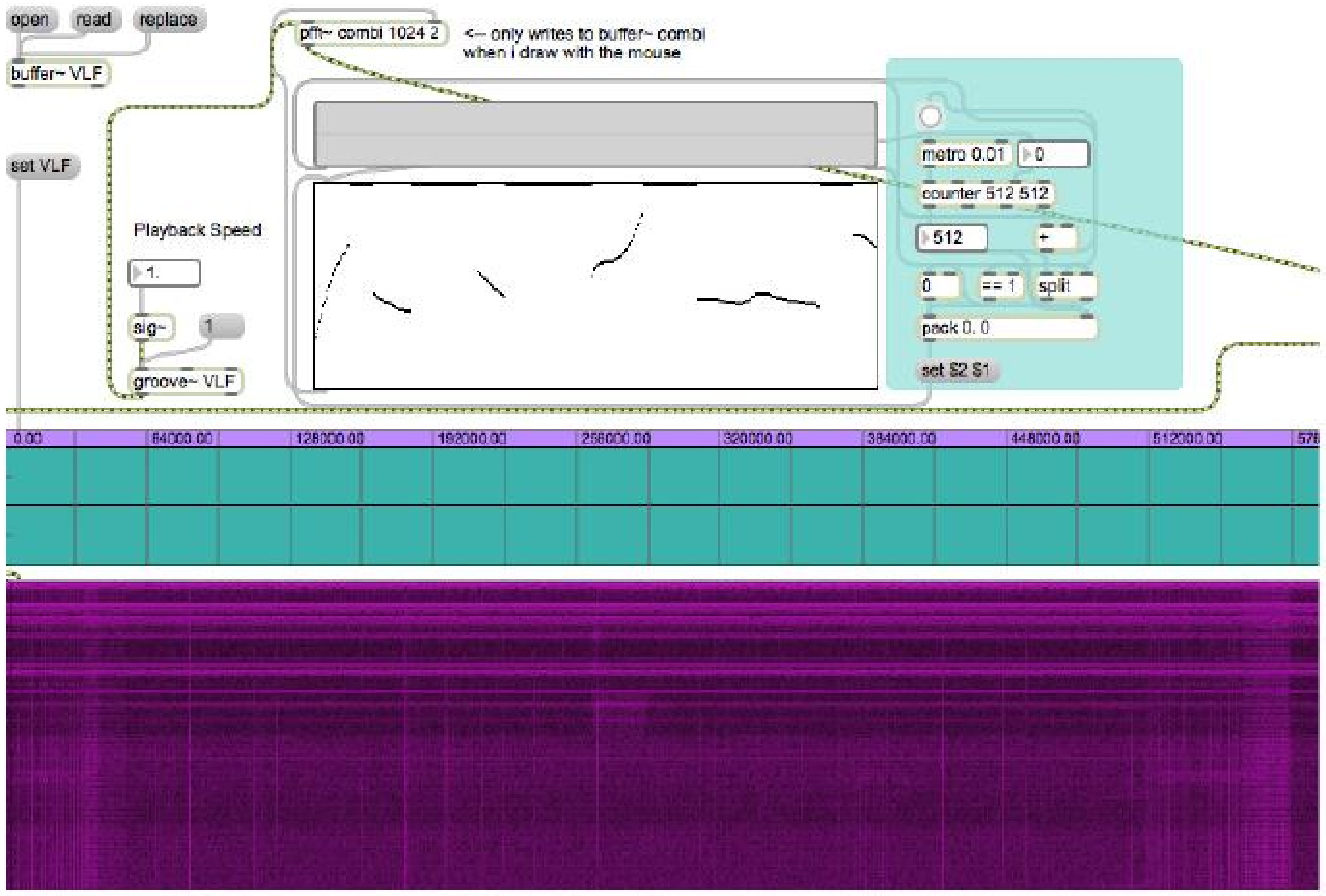
that have interesting areas of sound. This will result in the boosted bands being revealed, while the unchanged parts of the signal remain cancelled out.

Other Useful Tools:
PD and max/MSP are visual programming languages that allow you to build bespoke audio processing software. To filter VLF signals more effectively I built a narrow band FFT filter. This allows me to select very small bands of an audio signal, amplifying or removing wanted/unwanted information. The software provides a very precise filtering and isolation method.
PD is freely available for Mac, PC, Linux and Unix. Max/MSP is commercially available for Mac and PC.

Spear – This software resynthesizes sound files using a large bank of sine waves. You can then perform advanced operations such as isolating small frequency areas, editing the volume of individual frequencies and elongating frequencies. Freely available on Mac and PC.

Spectral Gate – Spectral gates allow you to gate or duck some bands of frequency without affecting others.
Some plugins are:
• Michael Norris – Soundmagic Spectral
• Soundhack – Spectral Shapers plugins

Creative Processing:
All the methods and tools mentioned above are able to be used creatively with some experimentation and imagination. A tool that I



max/MSP FFT filter.

have found very effective is a granular synthesis patch I made with max/MSP. This plays grain streams back at variable pitch rates and creates eerie and beautiful soundscapes from VLF recordings.

VLF SOUND DIARIES

Over the last few years I have travelled to some amazing places as part of my adventures with VLF sound. This section presents some of my most interesting experiences and looks at the sound I was hearing, the equipment I was using and the exact longitude and latitude where these recordings took place.

This section also contains a guest sound diary page from composer and sound artist Thomas Rex Beverley. Thomas's recent project Chihuahuan involved him riding by bike from San Diego, California to Fort Davis, Texas, with the purpose of recording the sonic environment using a number of different methods.
One of these methods was recording the electromagnetic spectrum with a VLF receiver made from the instructions in "How to Listen to VLF: A DIY Receiver" in the first edition of this guide. His journey captured some wonderful sonic and visual landscapes that I'm excited to share with you

How to Read the Diaries
Each sound diary starts by stating the location where the recording takes place, alongside coordinates of longitude and latitude.

Below this there is a breakdown of the equipment used for the recording and a list of key sounds heard.

The text section shares my reactions and thoughts taken from my VLF journal.

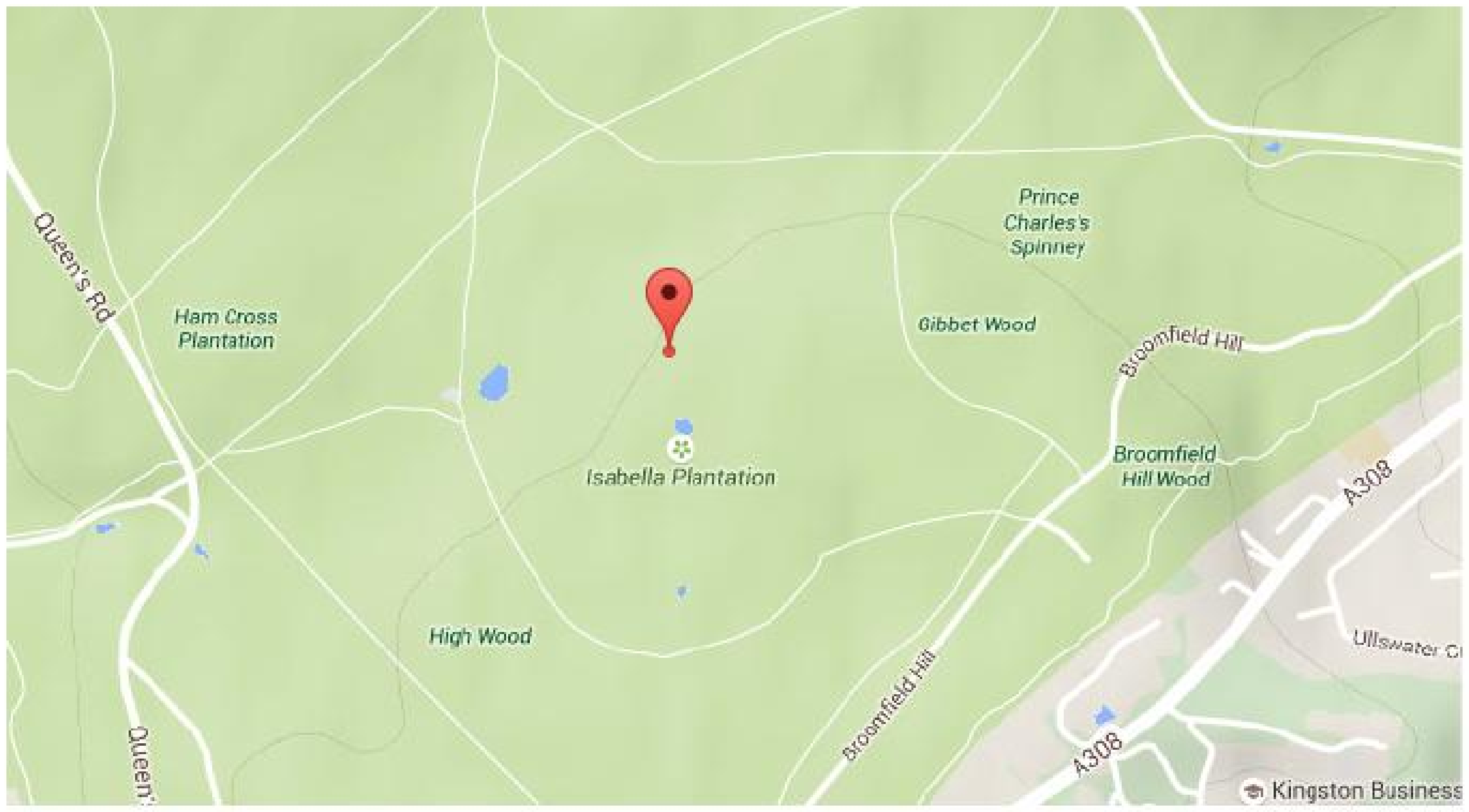
Keeping a visual and written journal of your VLF listening practice is something I'd highly recommend. It allows you to quickly look back at your recording expeditions, see where you were, what equipment you where using and your immediate thoughts in response to the sounds you were hearing. I keep a written journal but know many people who log their recordings through a spoken log on a dictaphone.

I hope the images and text over the next few pages inspire you to go out searching for your own VLF sounds.

RICHMOND PARK 51°26'04.5"N 0°16'38.1"W

Equipment
Zoom H4N
Single Receiver

Key Sounds
Sparse sferics
Unknown low frequency oscillation
Radio transmission
Possible Sun spot activity



The first recording I did after building my inductor was in Richmond Park. Richmond Park is a large open park situated in outer London. It was the perfect place to put a bit of distance between the city and myself, leaving my recordings with less mains hum.

I recorded for a period of around 30 minutes walking around the outskirts of an enclosed section of the park called Isabella Plantation.

The recording begins at low level, fairly sparsely populated with some distant sferics. An interesting sound picked up alongside this was a low frequency sound, which quickly oscillates. I have tried filtering the sound using an FFT band filtering device which I made for this purpose using max/MSP; however, there was a fair amount of activity in this part of the frequency spectrum, making it hard to sufficiently isolate the signal and thus determine whether it came from a natural or electronic source.

*Note: This sound has re-occurred in several other recordings. I have been unable to categorically identify its origin (I originally believed it to be solar wind or a characteristic of my inductor/recording device). From research it seems that it may be generated from distant power cables and train lines, both of which generate large amounts of electricity.

Halfway into the recording a large amount of digital disturbance occurs. This disturbance has characteristics of nearby mobile phone activity. Snatches of radio and telephone conversation can be briefly heard intermittently throughout the recording.

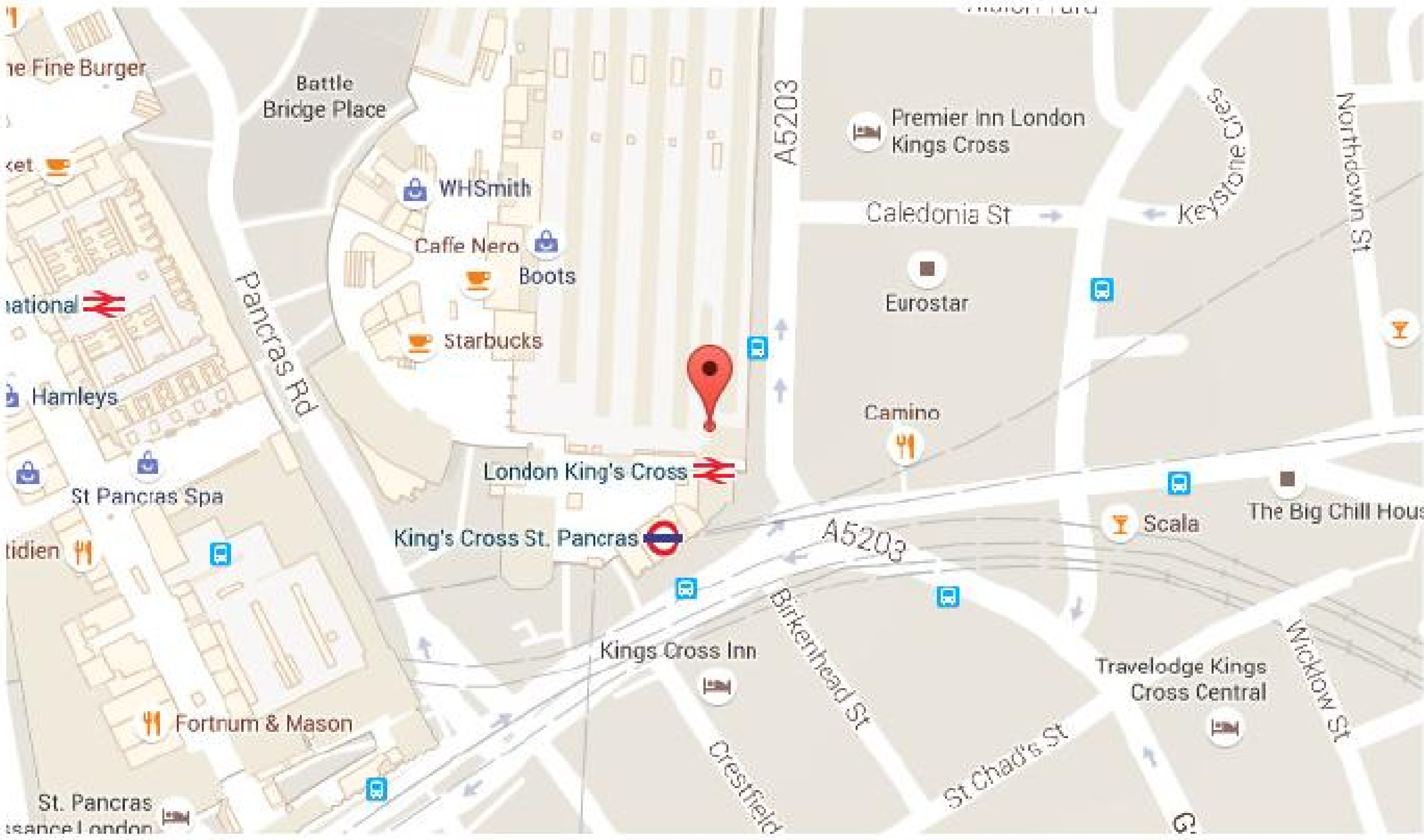
Above ground
Piccadilly line

LONDON UNDERGROUND

51°31'51.7"N 0°07'22.5"W

Equipment
Olympus LS-100
Single Receiver
Induction Pickup

Key Sounds
Hum from the high powered electric lights
Loud whistling and glitching from
the trains motor
High pitched tones produced by
railside power boxes



Shortly after I began recording VLF signals I became very interested in the electromagnetic emissions of the city. I had built my receiver with the intention of listening to the sferics, tweeks and whistlers of natural radio but because of the inner city interference I was able to hear a beautiful sonic interplay between natural and technological signals. This led me to embrace the city.

This specific recording expedition began in Camley Street Natural Park in London where I was meeting radio producer Patrick Sykes as part of a documentary on VLF called *Sunsong*. We began by recording the VLF signals of the park and then moved to the nearby King's Cross station, with the aim of recording the VLF sounds produced by the London Underground.

The sound on the platform was predominately the hum produced by the lights but as the train approached a high whistle came into focus with a lower, dirtier sound produced by its motor. Stepping onto the train dramatically increased the level of both these sounds.

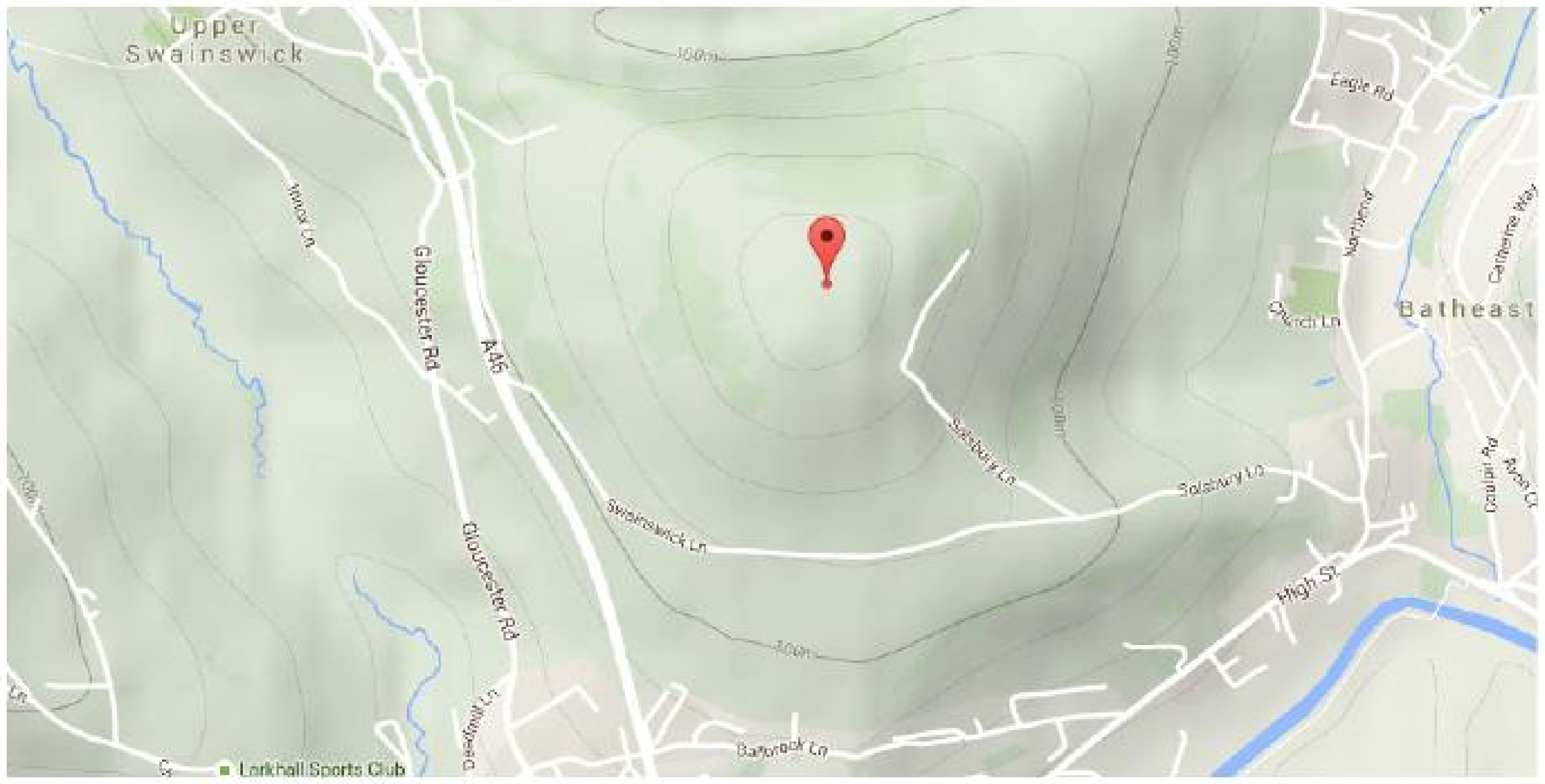
An especially interesting sound came from the train quickly passing by rail-side power boxes. These made tones varying in pitch that faded away at different rates depending on their placement and how fast the train was moving at the time.

After this recording session I was inspired to explore the VLF sounds of the London Underground in greater depth, developing these recordings into an audio-visual work called Changing Signals.

SOLSBURY HILL 51°24'36.5"N 2°20'02.8"W

Equipment
Zoom H4N
Dual Receivers
FiiO E06

Key Sounds
Sferics
Radio transmission from the USA



Solsbury Hill is a small hill just outside of Bath, UK. The hill was the site of an Iron Age fort.

I performed a number of recordings on the hill to see if it would be an appropriate venue for a VLF sound installation called A Machine to Listen to the Sky, involving a large tethered weather balloon, elevating two VLF receivers and broadcasting the sound of the sky back to ground level. The hill has a view straight over the city of Bath making it a very picturesque recording site. In this picture I am recording VLF whilst also using several small helium balloons to test wind level.

I recorded for a period of around 30-40 minutes and picked up a large amount of radio broadcast activity alongside natural signals such as sferics. One broadcast appeared to be coming from a religious radio station somewhere in America. It included prayer songs and a preacher passionately proclaiming about the evils of the United Nations: “The kingdom of darkness against the kingdom of light” and “times of trouble, times of trepidation.” This proved for rather unsettling listening as the broadcast rose and fell becoming one with the sferics and then overpowering them as it came back into the forefront of the recording.

I have no idea if this broadcast was directly coming from America or being re-broadcast or boosted from another area. It is worth noting that directly across from the hill stands a large TV broadcasting aerial – maybe this contributed to the broadcast I was receiving?

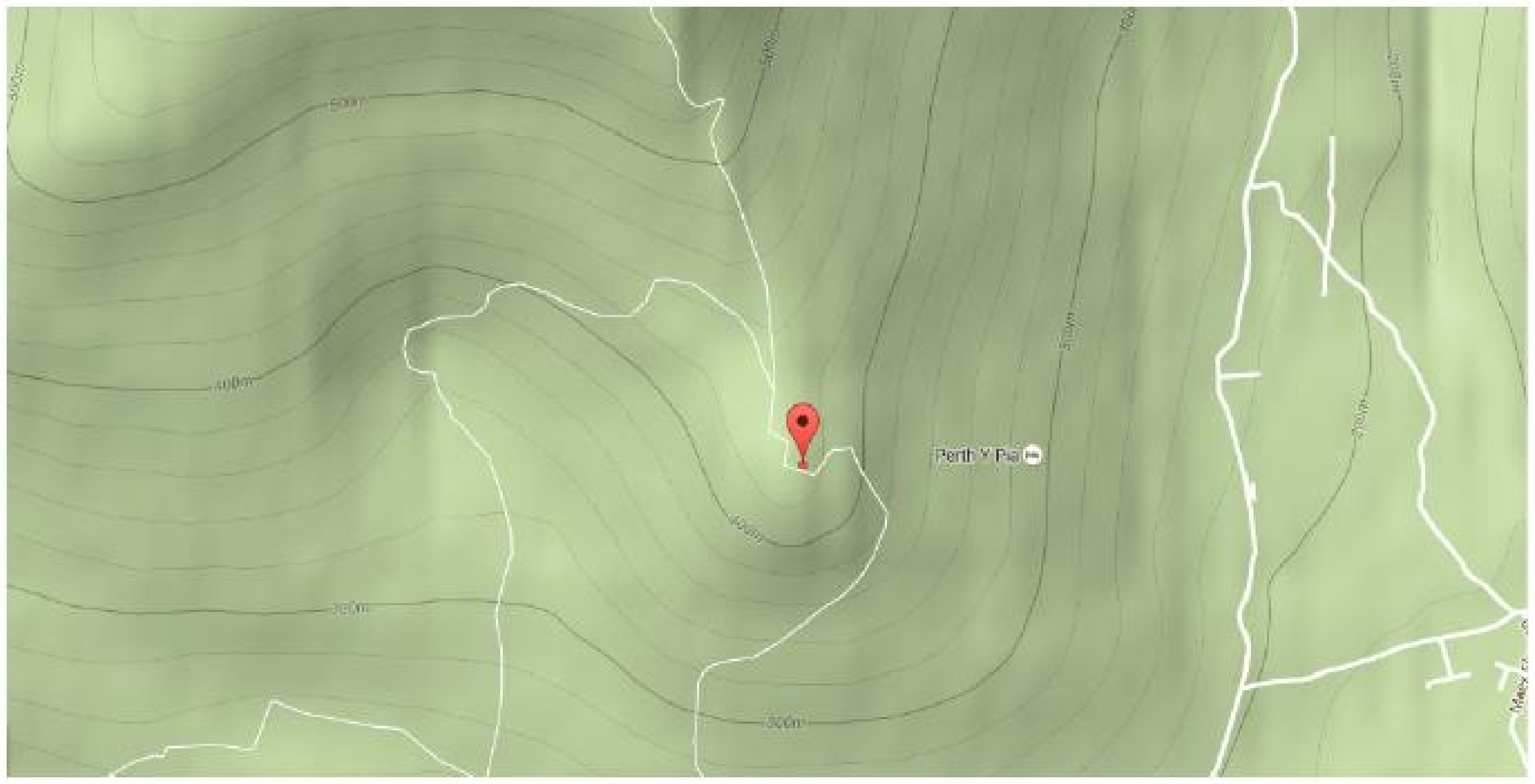
Several subsequent recordings in similar areas have picked up similar broadcasts, some sounding like they have the same preacher expounding his doctrine.

BRECON BEACONS

51°52′45.9″N 3°07′34.3″W

Equipment
Olympus LS-100
Single Receiver

Key Sounds
Sferics
Tweeks
Mobile phone signals
Electrical activity from the Olympus LS-100



I took a series of recordings on a recent trip to the Black Mountains in Wales. I was staying in the small village of Llanbedr, in the heart of the Brecon Beacons National Park. This particular recording took place on a sunny but chilly day on a mountain just outside Llanbedr called Table Mountain.

For this expedition I was carrying a very minimal setup. This consisted of a single receiver, Olympus LS-100 and a pair of headphones. During my hike up the mountain I came across a sturdy branch that I picked up with the aim of tying my receiver to it and staking it in the ground whilst recording. The added benefit was that I was able to use this as a walking stick to aid me up the mountain.

Once I had reached the summit I sat down and caught my breath, looking over the stunning scenery before setting up my recording setup.

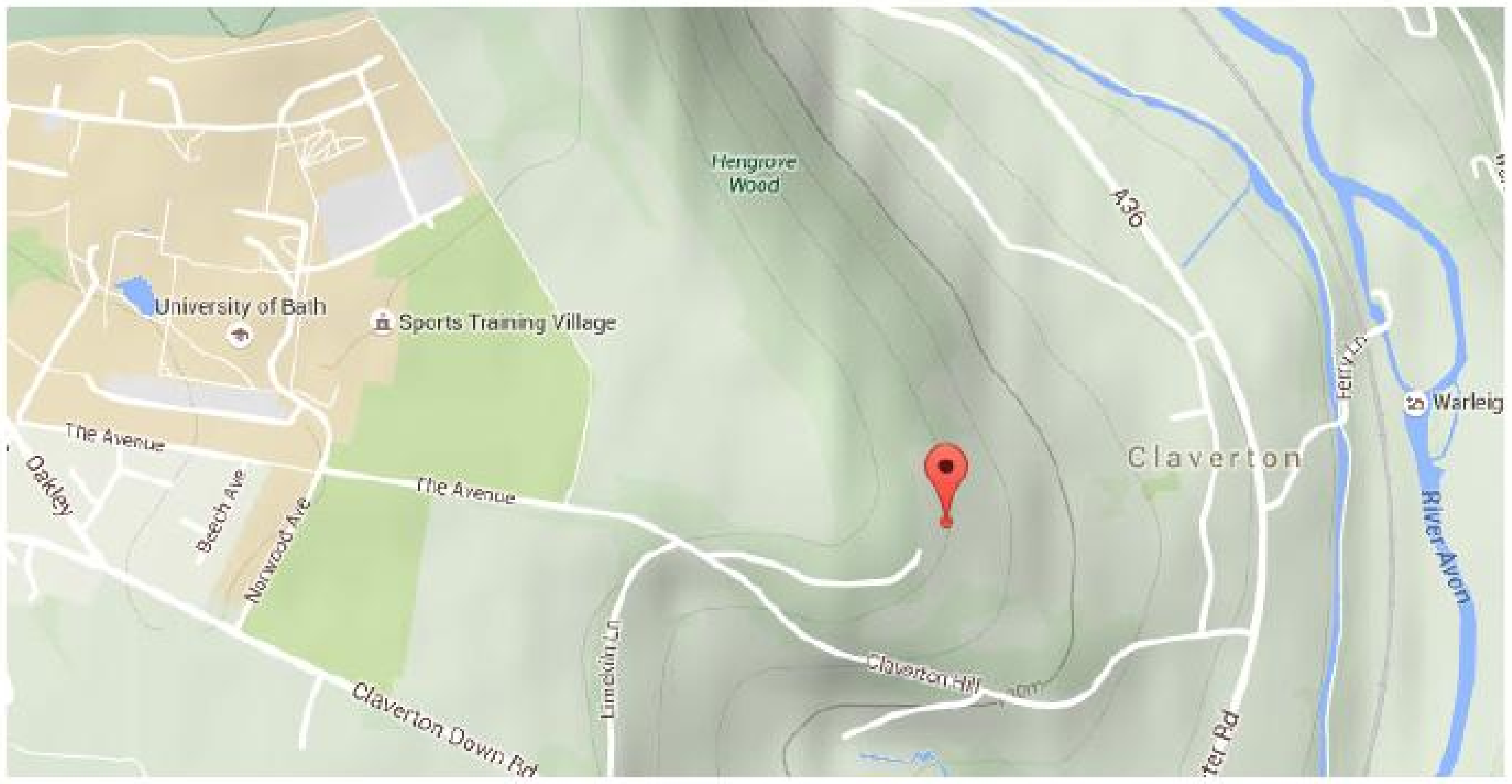
Recording on the summits of mountains in Wales has been the largest amount of distance I have been able to put between myself and cities which generate lots of electrical hum. The recordings are probably the best examples of natural radio that I have recorded. However I was not fully able to escape the sounds of the modern world. Low level radio broadcasts occasionally interrupted, while the 50Hz electrical hum could still be faintly heard. A harsh electronic sound alternating between oscillating and clicking also occurred for a short period of time. I really enjoyed listening to natural radio with snippets of manmade interference, but on a deeper level it made me wonder if there are many places left that aren't polluted by the residue of modern technology and communications.

A MACHINE TO LISTEN TO THE SKY

51°22'30.7"N 2°18'39.1"W

Equipment
Zoom H4N
Dual Receivers
FiiO E06

Key Sounds
Sferics
Tweeks
Radio transmission from the USA
Sunspot activity



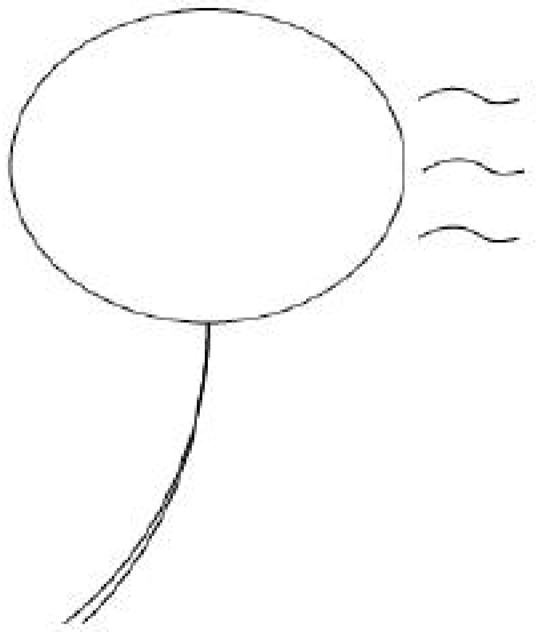
A Machine To Listen To The Sky is an audio-visual installation based around hearing the unheard. It was displayed at The American Museum in Britain on Thursday, 2nd May 2013. The installation consisted of two VLF receivers elevated high above ground level by a tethered weather balloon. The outputs of the two receivers were presented to listeners in the museum's grounds through a pair of headphones. The listeners were asked to draw graphical representations of the sound world they were hearing.

One of the aims of the project was to demystify these signals that are hidden but all around us and prove that they are available to present artistically, separately from scientific applications. I produced a short information sheet explaining what the listeners were hearing

Over the course of the day listeners came and went, listening to a great range of VLF signals. These spanned from sferics and tweeks to radio signals. Some were even lucky enough to hear some sun spot activity.

I invited visitors to draw a visual representation of what they where hearing to help them further engage with the project. On the next pages you can see the information sheet and some of the drawn reactions to the VLF spectrum from the installation.

A Machine To Listen To The Sky



You are listening to the raw sound of VLF.
VLF is a radio spectrum ranging from 3kHz to 30kHz. This is mostly below the range of any man-made radio broadcasts.
The signals you are hearing are produced naturally by the Earth's ionosphere and include storms, lightning strikes and the northern lights.
Technology also emits signals which fall into the VLF range an example of this is a low constant hum at around 50hz - this is produced by the power grid and becomes quieter or louder depending how near you are to a mains power source.

What are you going to hear?

Spherics: These are atmospheric disturbances caused by lightning. These signals can be picked up from thousands of miles away and manifest themselves as short sharp clicks. These are one of the more common sounds to hear whilst listening to VLF.

Tweaks: These are produced through similar disturbances to spherics, occuring when a signal is reflected from the ionosphere. Tweaks sound like birds tweeting.

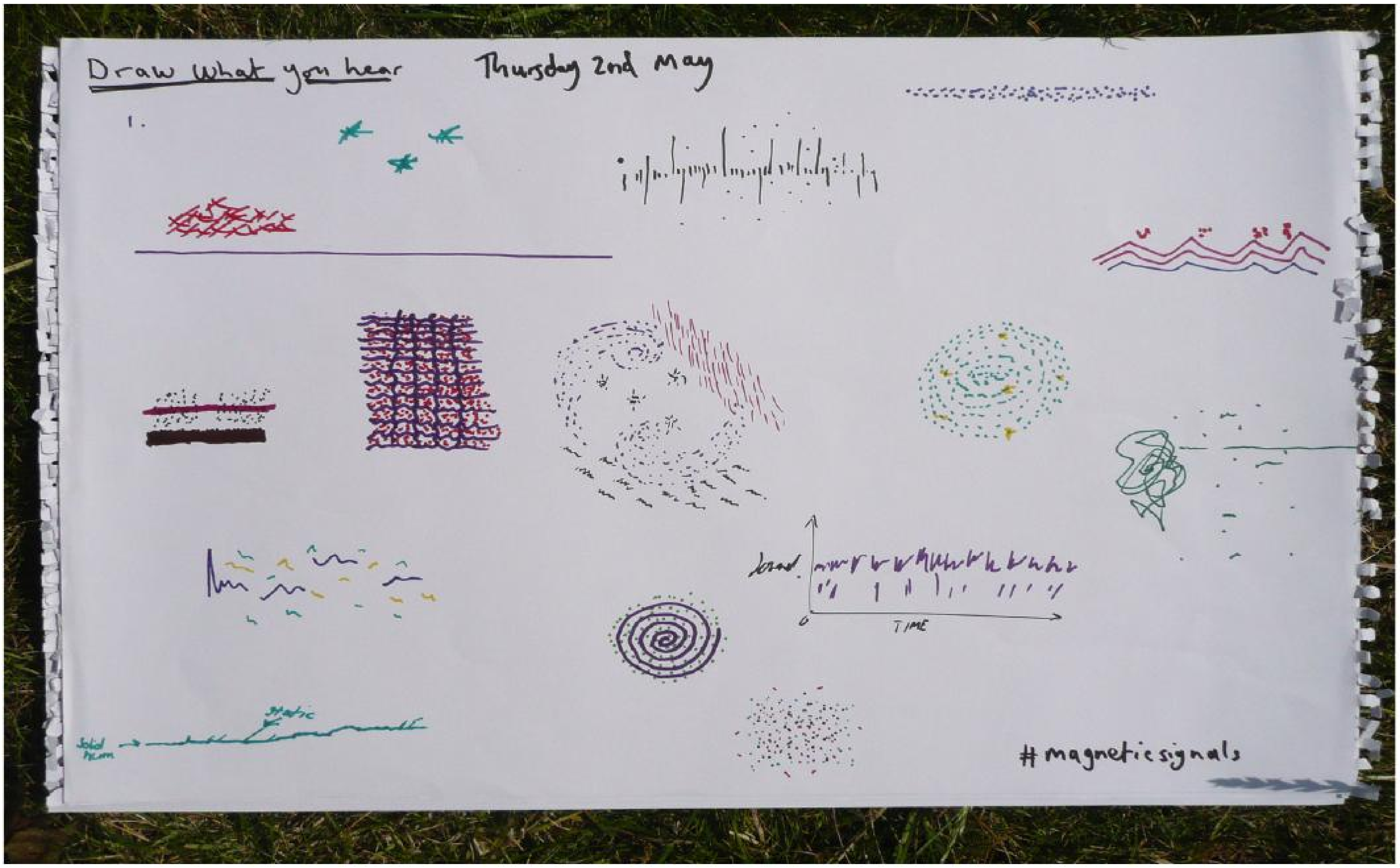
Man-Made Interference: A number of man-made signals can also be heard. A prominent sound is often from the electrical grid - a constant low hum. Mobile phone signals, satellite communications and some military communications using the VLF band can also be heard.

Rarer Sounds: If you're lucky you might hear sounds from signals produced by the Aurora Borealis. These sound like a large number of birds flocking. Solar wind also creates changes in the ionosphere that create VLF signals. A rarer by-product of lightning strikes are whistlers, these create a short high to low frequency whistle.

How Am I Hearing All This? The two circular devices are known as inductors. These are large loops of wire which respond to magnetic fluctuations. When the output is connected to an audio device these signals can be heard as audio and also recorded.
VLF is used in the scientific community to monitor space weather as well as seismic activity. As a sound artist the ability to hear an unheard spectrum of sound is very exciting and VLF opens a whole new world of artistic exploration and possibility.

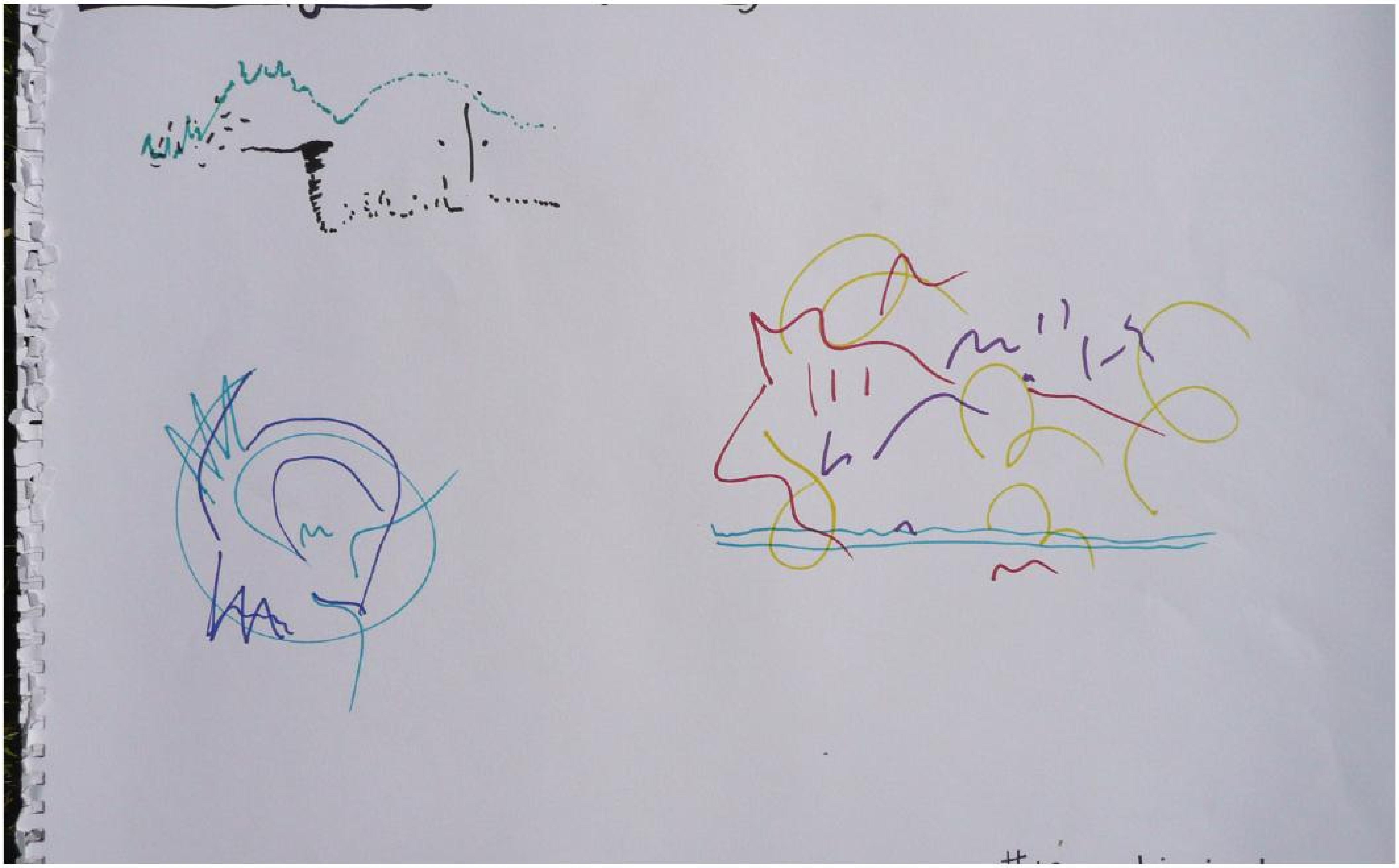
If you are interested to find out more about VLF and the "A Machine To Listen To The Sky" project head to **http://magneticsignals.tumblr.com/** which contains information on VLF such as how to make your own DIY inductor as well as cataloguing my VLF recording adventures.

Please share your experiences of the project on twitter by using **#magneticsignals**
Thank you.



Drawn responses to the VLF spectrum in A Machine to Listen to The Sky installation,

American Museum, Bath, UK



Drawn responses to the VLF spectrum in A Machine to Listen to The Sky exhibition, showing documentation from the installation.

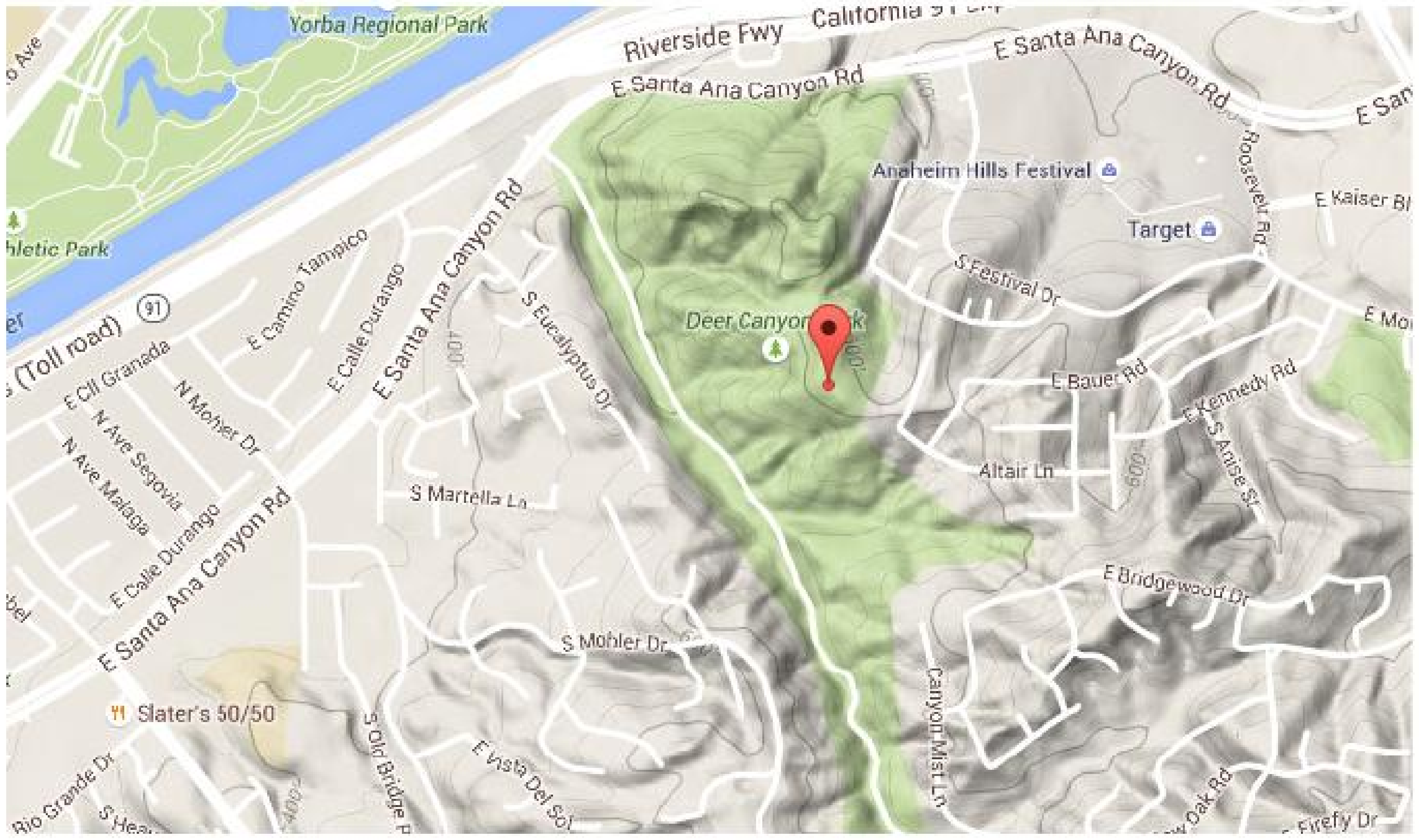
Burdalls Yard, Bath, UK

DEER CANYON PARK

33°51'45.2"N 117°45'18.9"W

Equipment
Olympus LS-100
Electrostatic VLF receiver

Key Sounds
Mains hum
Crackle of latent electricity



In the summer of 2014 I spent several months living in Southern California. This was the start of a series of travels in North America for a project called North American Sound Diaries that explores the North American continent through a series of sound documentaries, field recordings and electroacoustic compositions.

Rather than carrying my large loop receivers, I built a smaller electrostatic VLF receiver to use on my travels. On this particular recording I was hiking through Deer Canyon Park nature preserve near Anaheim Hills, California. I noticed two large electricity pylons stretching from one point of the canyon to the other. These pylons produced a fairly loud audible crackle of electricity. I was really fascinated by this sound and was intrigued to see how the area would sound through my VLF receiver.

I returned to the spot the next day and recorded, first the audible acoustic sound and then the VLF. As I had expected the main sound I picked up was the constant hum of the power grid with none of the crackling of latent electricity I could audibly hear. Even so this was an exciting experience for me as I was able to listen to audibly hear the electricity coming from the pylons alongside the hum coming into the VLF receiver.

DESERT STORM CHASING

THOMAS REX BEVERLEY

Equipment
Zoom H6
Single Inductor

Key Sounds
Sferics and Tweeks recorded from a lightning storm in west Texas

Thomas Rex Beveley is an American composer and media artist. His work often incorporates data taken from nature. His most recent project *Chihuahuan* – a multimedia album that changes with the seasons – involved Thomas cycling from San Diego, California to Fort Davis, Texas collecting sound and weather data. A key piece of equipment on this trip was a VLF receiver made from the instructions on pages 8-10. I asked Thomas to write a short passage about his use of the VLF receiver for the updated edition of the guide.

You can find out more about Thomas and his work *here* and how to experience Chihuahuan *here*.

"Throughout a 1,000 mile bicycle trip across the American Southwest this summer I used a Very Low Frequency (VLF) receiver. I was mainly interested in recording the sound of electromagnetic energy from lightning in parallel with the acoustic sounds of nearby storms. I set up the VLF receiver and also recorded with the built in microphones on my Zoom H6. I was caught in one amazing storm in west Texas with a staggering amount of lightning. I would see the lightning, hear the sound from the VLF receiver instantly, and then 1 to 5 seconds later hear the acoustic sound of the thunder through the Zoom microphones. This use of the VLF receiver was the most profound and interesting of the trip. It was stunning the hear lightning through both its electromagnetic and acoustic manifestations."

Thomas Rex Beverley

RESOURCES

Here is a list of resources that can be useful for continuing to learn and listen to VLF.

Some Call it Noise, a broadcast work made by Dan Tapper combining recordings from a number of artists working in the field of VLF alongside interviews with artists and scientists.

Radio Nature, a fascinating book on VLF by Renato Romero.

Sunsong, a radio documentary on VLF by Patrick Sykes.

VLF extraordinaire **Stephen P. Mcgreevy** has been recording VLF for many years and has a great wealth of information available online.

A website on astrophotography by **Joel Gonzalez** with some information on building a VLF receiver.

News and information about the Sun-Earth environment can be used to monitor for high periods of solar activity – often a good time to listen to VLF.

Natural Radio VLF Discussion Group on Yahoo.

CARISMA's website contains a wealth of information about earth's magnetic field as well as freely available data from CARISMA itself.

CREDITS AND THANKS

Photo Credits:
Richard Tapper – Cover, pages 9, 18, 20, 33
Thomas Rex Beverley – pages 11, 36
Claude Wittman – page 11
Juna Abrams – page 15
Patrick Sykes – page 22
Andrei Branea – page 26
Dan Tapper – all other uncredited images
Edited and designed by Juna Abrams

Thanks:
Thanks go to all the contributors to the guide, everyone who has contacted me with their VLF adventures and images of their receivers, New Adventures in Sound Art (NAISA) who gave me a platform to develop the guide into several VLF workshops, and Juna Abrams for designing and editing the guide.

ARTIST'S NOTE

I was inspired to create this new edition of VLF: A Sound Artist's guide from developing the contents of the guide into a series of workshops. These workshops were a great opportunity to see what translated well when explaining VLF to people completely new to the subject.

This new edition takes from these experiences and tries to present VLF and the technical aspects of listening to and building VLF receivers in a clearer and more in depth way.

I hope this edition has content to interest previous readers and inspire new readers alike.

A real thrill has been receiving communications from people who have read the guide and have gone out and begun their own VLF adventures. Please don't hesitate to get in touch with questions and pictures of your VLF gear.

You can find contact details on my website: www.dantappersounddesign.com and keep up to date with my work with VLF on my blog: www.magneticsignals.tumblr.com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