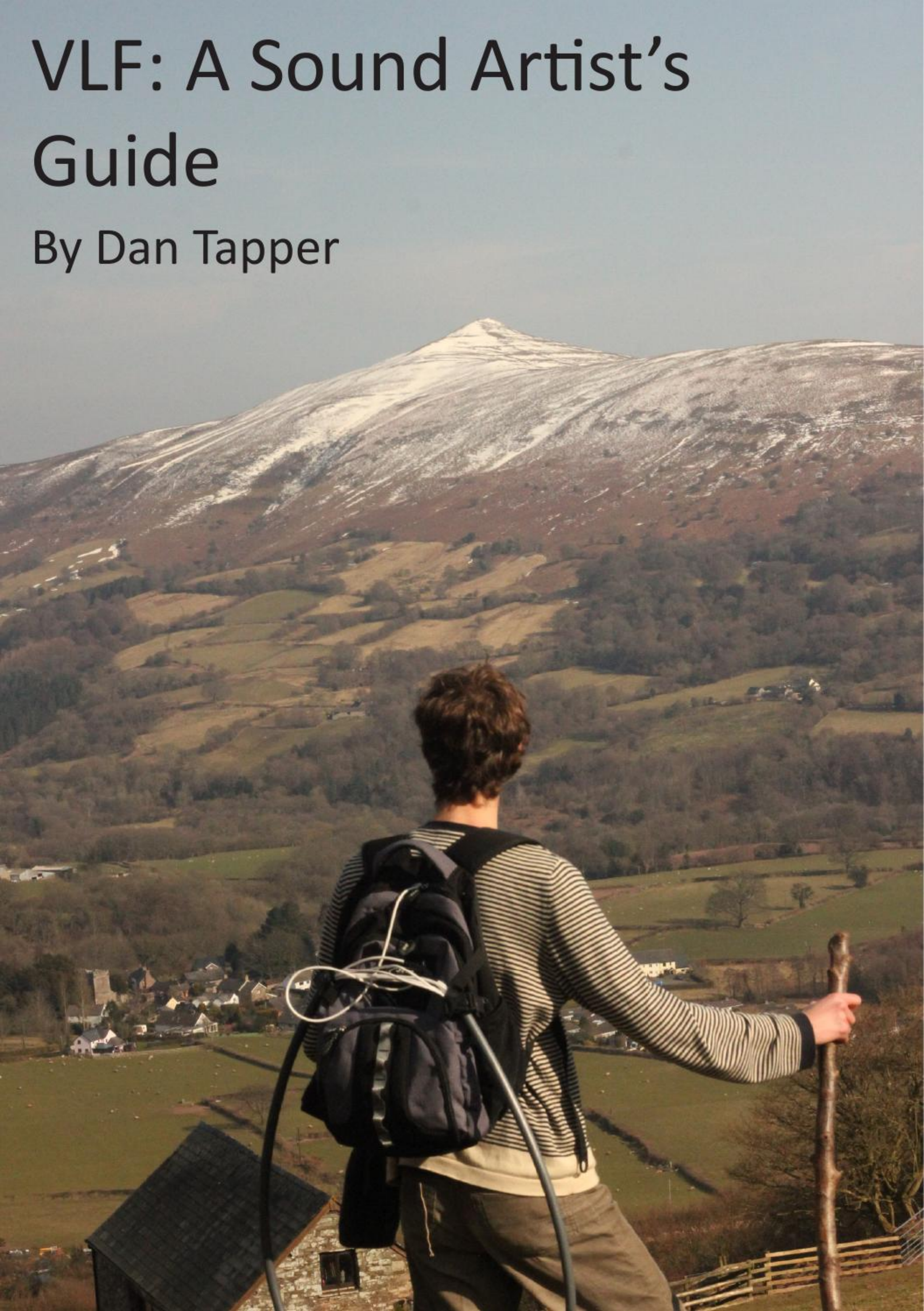
VLF: A Sound Artist's Guide

By Dan Tapper



Intro

My name is Dan Tapper. I am a sound artist, recordist and sound designer. Over the past year I have become very interested in recording and using VLF (Very Low Frequency) signals in my work.

VLF is a frequency band of the electromagnetic spectrum and allows you to hear all sorts of interesting things such as naturally produced radio signals (lightning, sunspots, northern lights, etc...) and also man made ones (radio transmission, mobile phone signals, etc…)

I think VLF is important because it reveals a rich area of sound that is hidden to us without the use of special equipment. These sounds however are very much there and are part of our world and natural order of things. These sounds also shed a light on the sorts of electromagnetic emissions man made technology is making.

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 any man made radio broadcasts.
The signals in this band 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.

How do you listen to VLF?
We listen to VLF through devices 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.

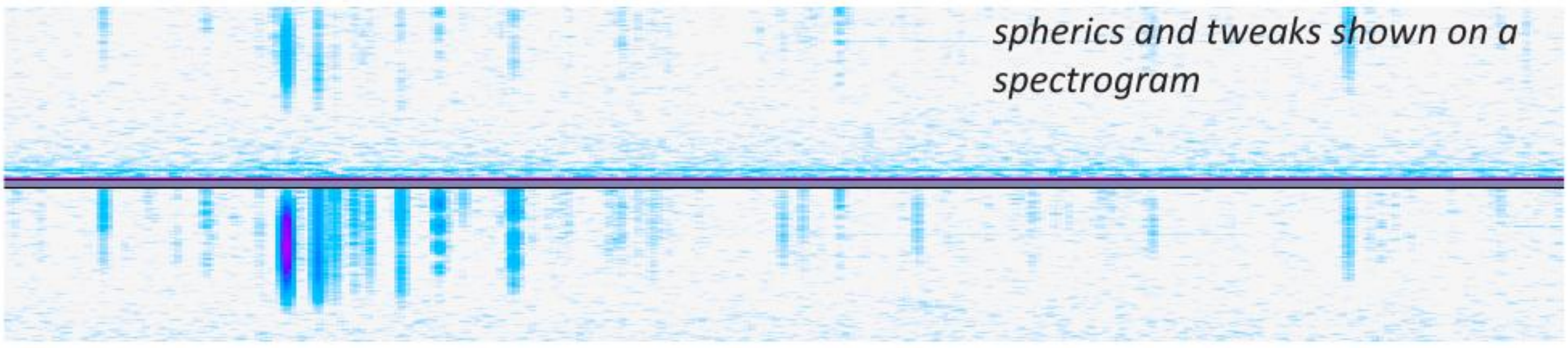
VLF is used in the scientific community to monitor space weather as well as seismic activity. For a sound artist the ability to hear an unheard spectrum of sound is very exciting and VLF opens a whole new world of artistic exploration and possibility.

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

Some Things You Should Expect 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.

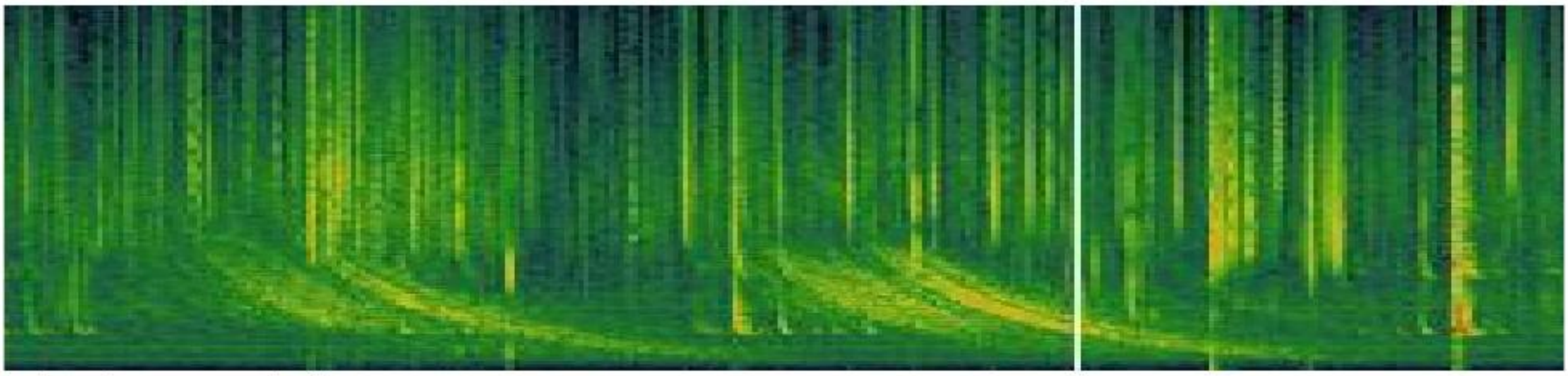
Tweaks:
These are produced through similar disturbances to spherics, occuring when a signal is reflected from the ionosphere. Tweaks sound like birds tweeting.



spherics and tweaks shown on a spectrogram

Buzzer:
Caused by signals being passed between clouds. The noise created is similar to that of bees.

Whistlers:
A rarer by-product of lightning strikes are whistlers, these create a short high to low frequency whistle.



Whistlers recorded by Dave Ewer
http://www.vlf.it/davegallery/davegallery_2010w.html

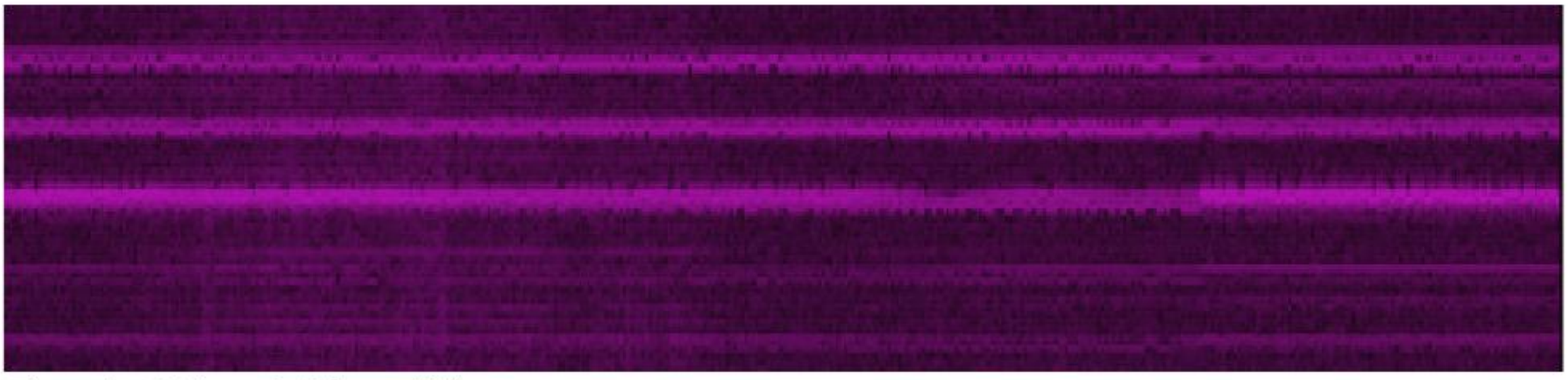
Northern Lights:

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.

Northern Lights in Manitoba, Canada
Steve P Mcgreevy
http://www.auroralchorus.com/natradio.htm

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 at around 50Hz. Mobile phone signals, satellite communications and some military communications using the VLF band can also be heard.



Electric Grid on Solsbury Hill

How to Listen to VLF:
A DIY Receiver

Materials:

• ***Frame*** - my inductor is made from a hula hoop but you can use anything you want.

• ***Copper wire*** - you'll need 100ft or more

• ***Electrical tape -*** or some kind of insulating material

• ***Jack plug*** - this allows you to listen to the output of your receiver; it's your choice what plug type you use. I've chosen an unbalanced jack plug and it seems to work well

• ***Solder***

• ***Soldering iron***

Making:

My hula hoop has a diameter of 0.8 metres. This is going to become the frame for my receiver. To do this I cut the hoop with a pair of scissors, leaving me with a hollow circular tube. I then begin to thread my wire through this.

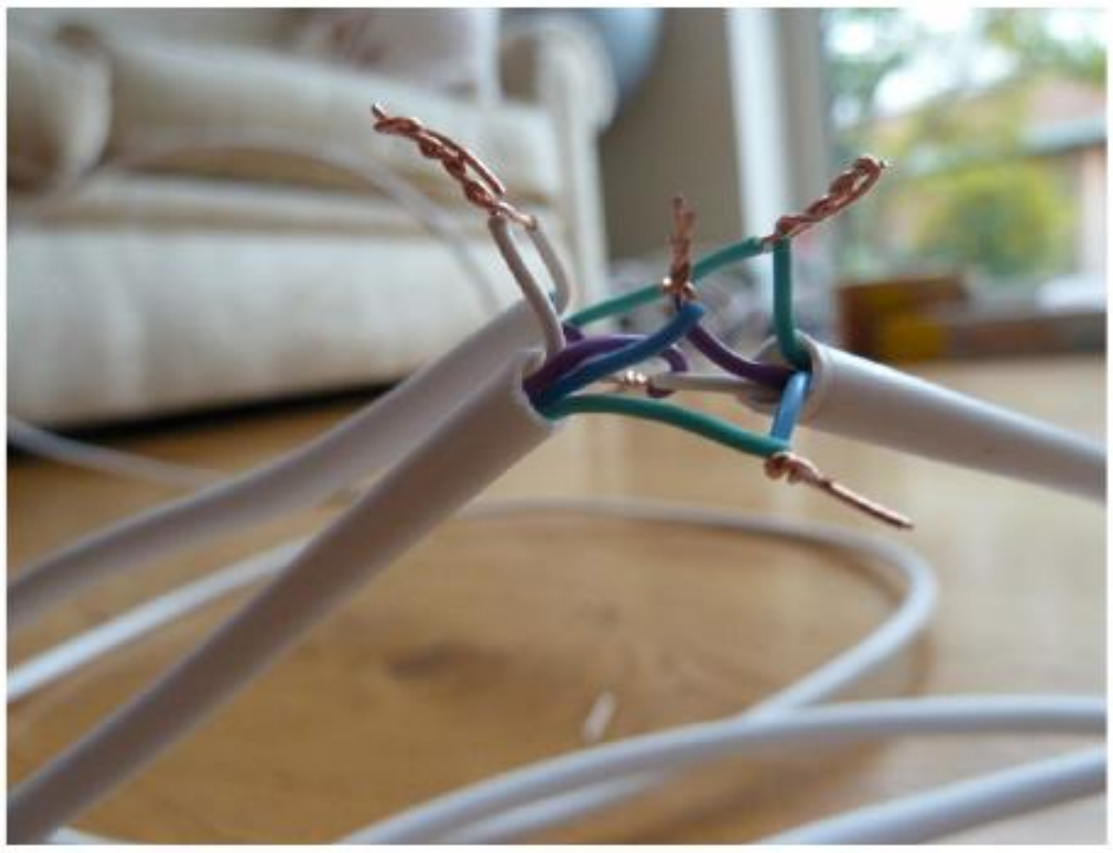
I am using 18 metres of shielded four-core signal cable. To increase the length of my wire I connect the cores in series after I have looped as many turns as I can through the tube.

To determine the amount of wire you need 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 metres. To work out the right amount of wire you'll need for your receiver it is important to first determine the diameter of your frame. In this

case it is 0.8 metres. 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)



0.4 x 0.4 = 0.16
0.16 x 3.142 = 0.5 square metres - this is the area that our loop circumscribes.

To work out the amount of wire you need or have used you multiply the number of turns by the circumscribed area – for this receiver I looped my four-core wire 7 times, which when connected in series is equal to 28 turns.

28 x 0.5 = 14 square metres, which is the effective/circumscribed area of my VLF loop receiver.

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 to a jack plug and listening through a battery-powered amplifier. If everything is behaving as it should you can 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.

After this you are ready to go out and listen to the electromagnetic spectrum!

Further stuff:
If you are using your receiver a lot outdoors it might be useful to make a handle for it. I secured a thin piece of wood, which allows me to hold the receiver like an aerial and also stake it in the ground for extended periods of time.

Tools of the Trade - What Works Well with Listening to VLF Signals

It is important to have reliable recording and monitoring equipment to enhance your enjoyment of working with VLF. Luckily there are a number of devices cheaply available giving a large range of choice to the VLF artist and enthusiast. When purchasing equipment there are several important things to consider:

Inputs - The receiver we have just made is outputting through a TRS jack. When purchasing a recording device make sure that it has the appropriate inputs for your inductor. Many devices only support ¼ inch jack and not TRS and XLR inputs; it is possible to buy converters but this may result in a loss of signal quality and increases the amount of equipment you need to carry.

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. VLF enthusiasts often build their own pre-amplification devices for this purpose. From my experience however I found that building a pre-amp is a fiddly business. I resulted with a louder overall signal but noise and distortion where also introduced making listening unpleasant. I found that twinning an audio recorder with a FiiO E06 headphone amplifier made monitoring my recordings a lot easier to hear without adding hum. I would later digitally amplify my recordings on a computer.

Recorders

Olympus LS-11 - £200

A professional sound recordist recommended the Olympus LS-11 to me towards the beginning of my VLF journey. This was partly because it fit into my limited budget. I chose not to purchase it as aside from its inbuilt microphone it only featured one ¼ inch mic input. This meant I would have had to buy an adaptor for my inductor's output. Despite this decision it is a well respected recorder in an affordable price bracket.

Zoom H4N - £220

The Zoom H4N is an excellent, simple-to-use recorder with fairly good quality pre-amps. It's intuitive and you can begin recording in no time. It has two TRS and XLR inputs along with phantom power. It also allows a large amount of headphone amplification enabling you to monitor at high levels. The downside to the Zoom is that it runs on AA batteries, which don't last particularly long and are also a nuisance to carry around. Overall a very good recorder for the price.

Olympus LS-100 - £300

The Olympus LS-100 is a slightly higher quality recorder than the two previously mentioned. The extra money gives you a much more sturdily built device and extra bangs and whistles such as the possibility for multi-track recording. The main improvement is the LS-100's excellent pre-amp - allowing high amplification with no audible noise or distortion. It also uses lithium batteries which hold their charge much more effectively than AA. It is not without downsides however: The menu is needlessly in colour and isn't particularly intuitive or easy to navigate. It also has a sleep function which is tricky to turn off, and means you can't always visually monitor your recording level.

My Reccomendation

If I was recommending a recorder for a budding VLF artist I would tell them to buy the Zoom H4N as it is a great simple recorder which allows for high quality VLF recordings and doesn't break the bank.

I also would recommend buying audio equipment from **Solid State Sound,** a specialist in solid state recorders with good after purchase support: ***http://www.solidstatesound.co.uk/***

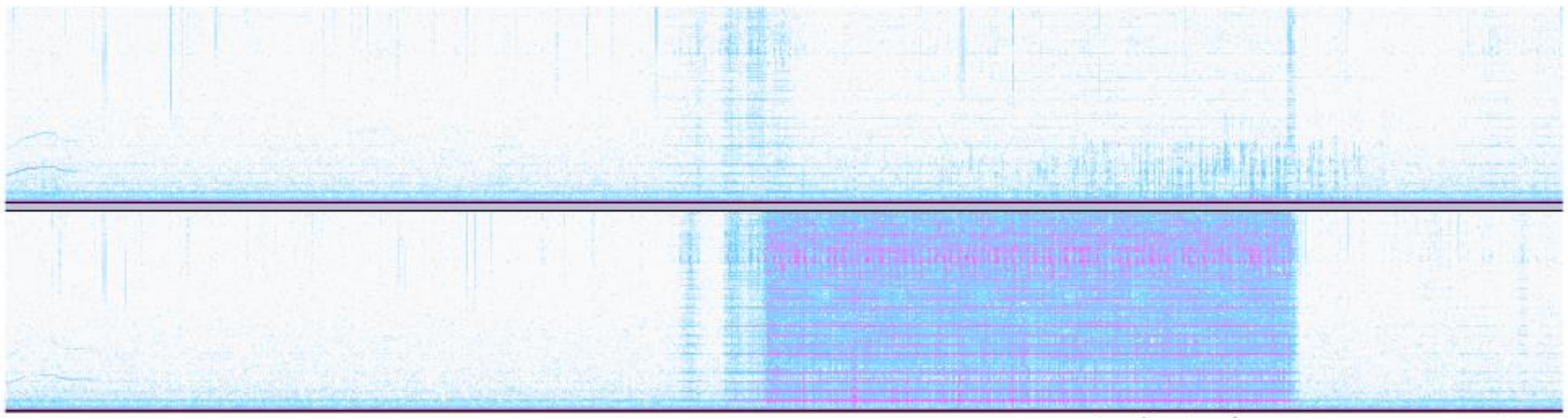
Processing and Isolating Signals

The VLF band contains a great deal of noise. As an artist and general enthusiast it is important to be able to find effective ways of listening to and processing VLF recordings.

Visual Analysis:

As VLF recordings are often taken over a period of time it becomes important to become acquainted with viewing your recordings visually. There are many programs available that allow you to view recordings in spectrogram form. A spectrogram is used to visually represent the spectrum of frequencies found in a sound. This allows you to identify areas of activity more quickly than you would be able to through a standard waveform or simply listening through your recordings. VLF phenomena have very distinctive shapes which appear on a spectrogram - an example of this are whistlers - which are represented by a downwards sweep of high to low frequency activity.

A useful program for spectrogram analysis is **Audacity**, freeware audio software with an effective spectrogram. It is also useful for amplifying and listening back to your recordings



Audacity's spectrogram view

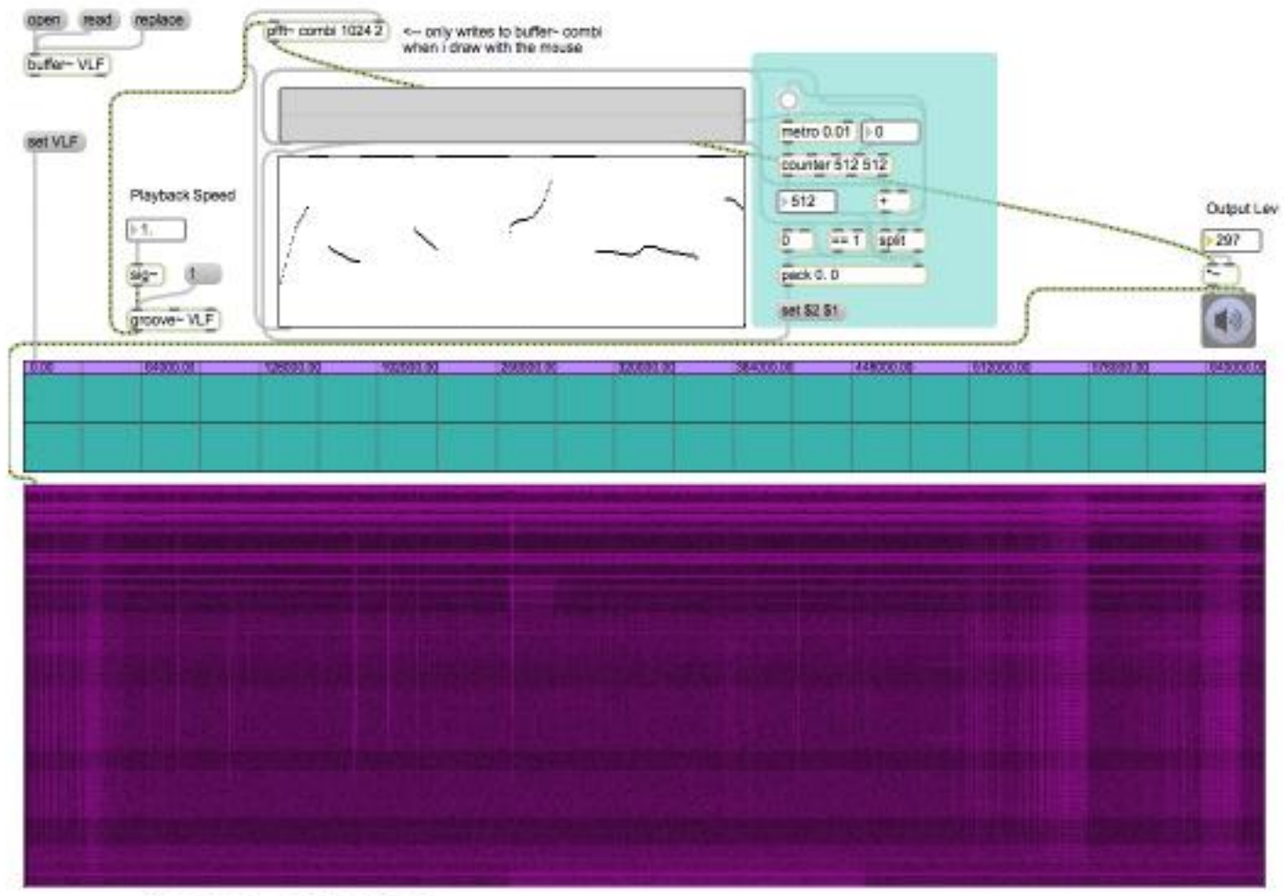
Filtering and Isolating Signals:

Once you have been able to identify areas of interest it may be necessary to isolate them from other noises in the VLF band. For this it is important to have an arsenal of filters and other signal isolating tricks. A simple fix is to use a banded EQ to boost and cut wanted and unwanted areas. However this doesn't always work. A more advanced isolation method is to 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 that have interesting areas of sound - this will result in the boosted bands being revealed. This method is filtering through phase relationships.

Other Useful Tools:

max/MSP - I used this to make my own bespoke narrow band FFT filter. This allowed me to select an individual or selection of points of a signal providing a very precise filtering and isolation method.



max/MSP FFT filter

Spear - This software resynthesizes your audio file 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, elongating frequencies. However as Spear resynthesizes your soundfile it reduces the clarity and quality of your VLF recordings - this is more of an artistic tool than analytical.

Spectral Gate - Spectral gates also allow you to isolate small frequency areas. Some plugins are:

- ***Michael Norris*** - Soundmagic Spectral
- ***Soundhack*** - Spectral Shapers plugins +spectralgate
- ***Logic Pro*** (native plugin) - Spectral Gate

Creative Processing:

VLF recordings carry a huge amount of interesting frequency information so are perfect for processing for creative purposes. All the methods and tools mentioned above are able to be used creatively with a little experimentation and imagination. A tool that I have found very effective is a variable pitch granular synthesis patch made with max/MSP. This plays grain streams back at variable pitch rates and creates eerie and beautiful soundscapes from my VLF recordings.

My VLF Adventures

Richmond Park

Equipment:
Zoom H4N
Single Inductor

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 park called Isabella Plantation.

The recording begins at low level, fairly sparsely populated with some distant spherics. 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 comes 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 trainlines 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.

Solsbury Hill

Equipment:
Olympus LS-100
Dual Inductors
FiiO E06

Solsbury Hill is a small hill just outside of Bath, UK. It was made famous in a song by Peter Gabriel called Solsbury Hill. The hill was the site of an Iron Age fort.

This was the initial site where I imagined my installation a Machine To Listen To The Sky to take place as it has a view straight over the city of Bath, highlighting the counterpoint of natural and technological signals I wished to receive and bring attention to.

This trip was in effect a simple dry run of the final project to see if the site would be an effective performance area. For this I strapped my two inductors onto a tripod structure and three helium balloons were connected to the top of this to help me gauge wind levels/exposure.

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

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?

Brecon Beacons

Equipment:
Olympus LS-100
Single Inductor

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 inductor, Olympus LS-100 and a pair of headphones. During my hike up the mountain I came across a sturdy branch which I picked up with the aim of tying my inductor 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.

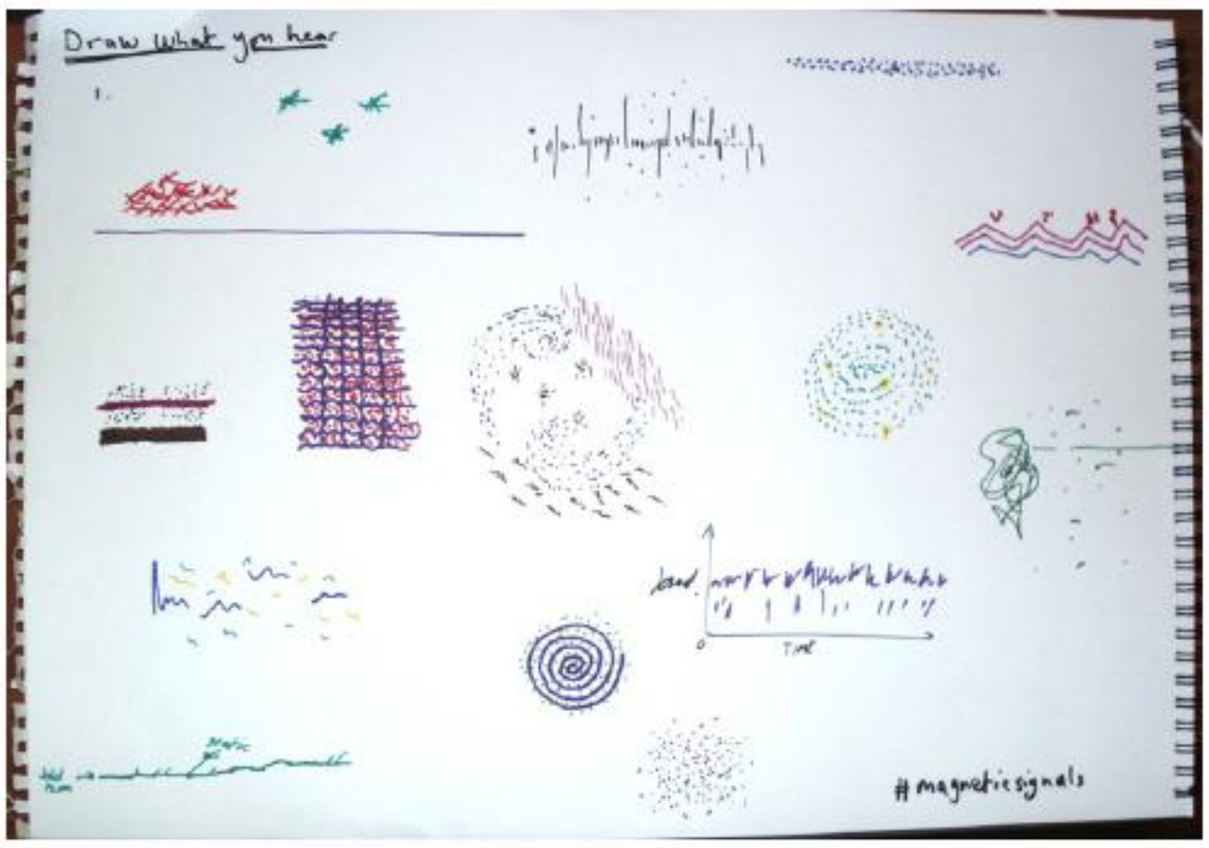
Recording on the summits of mountains in Wales has been the largest amount of distance I have been able to put between myself and cities which generate lots of electrical hum. The recordings are probably the best examples of natural radio that I have recorded. However I was not fully able to escape the sounds of the modern world. Low level radio broadcasts occasionally interrupt, while the 50hZ electrical hum can still be faintly heard. A harsh electronic sound alternating between oscillating and clicking also occurs for a short period of time. I really enjoyed listening to natural radio with snippets of man made 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

Equipment:
Zoom H4N
Dual Inductors
FiiO E06

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 inductor devices elevated high above ground level by a tethered weather balloon. The outputs of the two inductors 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.

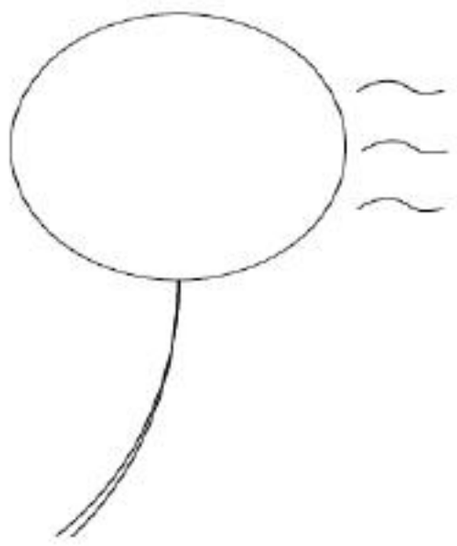
One of the aims of the project was to demystify these signals that are hidden but all around us and prove that they are available to present artistically, seperately from scientific applications. I produced a short information sheet explaining what the listeners were hearing (the sheet can be viewed on page 22).



Over the course of the day listeners came and went, listening to a great range of VLF signals. These spanned from spherics and tweaks (produced by lightning and energy transference between the ground, clouds and ionosphere) to radio signals which fittingly included some visitors hearing broadcasts originating from America - thousands of miles away. Some were even lucky enough to hear some sun spot activity.

Over three hours of VLF were recorded during the day. It is my intention to take these recordings and manipulate them to create an audio music work.

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.

Artist's Note

I hope you have enjoyed this manual and that it has inspred you to experiment with VLF for yourself. My journey has led me to a number of remarkable sounds and a desire to continue collecting audio and learning about the hidden world of sound that we live in.

You can keep up to date with my work on my blog:
www.magneticsignals.tumblr.com/
and please tweet me with any VLF related stuff @dantappersound

Don't forgot to **#magneticsignals**

Thanks go to

The American Museum - for graciously allowing me to perform my installation in their grounds.

Simon Bending and **Paul Reddish** - of the University of Bath Physics Department for making my installation possible by kindly donating the helium for the balloon.

Peter O'Brien - for filming the day's events.

Andrei Branea - for helping stake out Solsbury Hill on a very cold and windy day.

Richard Tapper - for helping me through various stages of the project and taking some fantastic photographs.

Juna Abrams - for patiently correcting my grammar mistakes.

The Bath Spa University **Creative Music Technology Department** - for inspiring me to try something different and helping me wade through red tape.