DROWNING IN ÆTHER;

Signal hunting as a tool

for exploring live performance and composition

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Abstract

Multitudes of signals surround us, most of which remain unheard heard by the human ear. This dissertation focuses on the audibility of satellite signals and describes the methods that have been developed in order to examine and render those signals audible to an audience. The research consists of three interconnected elements. The first is the reception diary that encompasses, archives and compiles data about captured signal transmissions, the act of which is referred to as "signal hunting". The next element is the performance, that immerses the audience into a distinct mode of listening to the audified signals, seamlessly intertwining those with narratives about the receptions. The last components are the sonic studies, exploring the signal body in multiple scales. From analyzing it's anatomy in a macro scale, to zooming out to a distance at which the signal appears almost inaudible. All three elements dynamically inform each other and influence their development. The research provides an in depth analysis of the audible qualities and effects of satellite signals in sonic studies and for an audience. It lays the foundation for an elaborate practice centered around the transmission of man-made objects orbiting the planet.

Contents

DROWNING IN ÆTHER

Introduction

In my practice, I am often fascinated by activities occurring in the earth's orbit. Currently, my interest is centered around the countless number of signals and indeterminate messages emitted by the artificial objects discreetly surrounding us. Multitudes of satellites transmit different rhythms and frequencies, spreading inaudible, encoded messages into what was once known as the æther. According to the Oxford dictionary definition[1], in archaic physics 'the æther' was described as a space-filling substance necessary as a transmission medium for the propagation of electromagnetic waves. But since the development of special relativity this concept got rejected. As of today the æther is defined as the upper regions of air beyond the clouds. Signal transmissions have been a persistent part of human history since the emergence of radio technology and we are now more than ever dependent on them. Many of our technological developments rely on radio technology. GPS, for example, is implemented in a multitude of everyday devices and is assisting them in tracking every move we make. Most of those signals are not meant to be heard by the human ear, those are the frequencies I am attracted to.

My current research focuses on signals transmitted by ghost satellites (refer to p.12). and outdated hijacked military satellites (refer to p.10). The former are space debris, malfunctioning objects floating in space that are no longer in use. Some of them still continuously communicate to earth even though nobody is listening to them anymore nor understands their data. They have outlived their designated function and their research programs have been shut down for decades, but despite that they do not withdraw, streaming continuously the silent proof of their presence. Others get lit by the sun while they orbit the earth and their solar panels occasionally are able to produce a bit of energy, just enough to start transmitting their messages for a brief moment until they enter the shadow of the planet and fall silent again. As they orbit the earth, they might

[1] "aether". oxforddictionaries Oxford University Press. https://en.oxforddictionaries.com/definition/ether (accessed May 22, 2019)

reappear a number of times per day, but sometimes their course may not line up with the hunter's location and one will not be able to encounter them for several months.

The latter are UHF[2] satellites hijacked by SATCOM[3] pirates. These man-made objects are in a geostationary orbit 36000 km from the earth and are mostly used by the U.S. military and NATO. Since these are first-generation satellites (launched in the 60s), the communication channel is open, not encrypted, so satellite radio pirates are capable of exploiting the satellites as their private worldwide CB-Radio[4] communication network. They not only converse with each other but also use that military equipment as their private entertainment network, occasionally playing music and sometimes, perhaps often, getting drunk while doing so.

Radio waves, Satellite signals, GPS, mobile phone conversations, all of these signals remain unheard by human ears as they infiltrate our cities and natural surroundings as tuning into these frequencies requires an extensive range of tools. For the last two years, I have been a researcher at the Institute of Sonology, during that time my project focused on the audibility of satellite signals through a practice-based approach. Part of the project involved developing a signal hunting toolkit (refer to p. 55) to capture and improvise with satellite signals. This personal toolkit is based on software-defined radio and various handmade antennas for capturing the signals, as well as a custom modular synthesizer for processing and improvising with the material.

This research is largely influenced by two communities that both share similar interests in radio waves but have different views and methods, specific to their realm. They both hunt for signals that surround us, but often stay their own audience. Radio amateurs are a very technology driven community, they thrive for clean signals and perfect antenna builds. Many share their antenna

[2] Ultra High Frequency

[3] Satellite communication

[4] Citizens band radio

construction plans and radio experiments to the public. They meticulously track the trajectories of satellites and compile historical as well as technical data about them. Ghost hunters try to engage with the paranormal, and use technology as a tool to shift the perception of their audience. They initiate ritualistic events, and manipulated radios are part of their toolkit to trick you into believing their acts. The line between those communities is often really thin, one can drift easily into conspiracy theories about aliens hijacking satellites (refer to p.14). These different interpretations of the energy of radio waves both inform and inspire my work. I like to traverse this line, get inspired and form my own understanding of working with radio signals. By appropriating some of the methods of both communities I develop my practice around signal hunting. In this research the term æther is used as an element to link these different worlds of imagination. And while none of these communities is interested in the acoustic qualities of the radio transmissions, I search for rhythms, patterns and qualities in the signals. The following chapters outline in detail the contextual as well as technical and artistic research and details encompassing the project.

Tuning in

The Radio receiver

The beginning of the research is centered around the basics of software-defined radio (SDR) and the construction of various antennas. SDR is a software implementation made from traditional radio components, such as tuners and demodulators. The RTL-SDR[5] dongle (see figure 1) used for this research, is originally designed as a DVB-T[6] Tuner dongle to watch digital TV or listen to local FM radio stations. Via an alternative driver[7] developed within the amateur radio community, the integrated chipset can be accessed as a wideband software defined radio. There are many different Digital signal processing (DSP) applications for software defined radio. SDR# for Windows, gqrx for Linux and SDRtouch for Android are used for this research.
The accessibility and mobility of software-defined radio play a crucial role in this research. Being able to move with the setup during outdoor performances is important when hunting radio waves from moving artificial objects. That would be impossible with most of the traditional radio equipment, which is heavy and usually not battery powered.

The advantage of these applications is the immediate representation of the signals in the spectrum analyzer and the intuitive control of the user interface. Most of the above mentioned radio software is open source which creates the possibility to access the source code, therefore extend the software or control it with external scripts (refer to 51.).

[5] Realtek software defined radio

[6] Digital Video Broadcasting — Terrestrial

[7] a group of hackers discovered that the raw data from the integrated RTL2832U chipset, that the USB device is based on, could be accessed directly with the help of an alternative driver and therefore could be used as a wideband software defined radio. Initially, the device is limited to operate from 87.5 MHz to 108 MHz for FM Broadcast Radio and from 474 MHz - 786 MHz for DVB-T. With the updated drivers the SDR dongle is able to receive frequencies between 24 MHz and 1766 MHz;
rtl-sdr.com. “ABOUT RTL-SDR” rtl-sdr.com. https://www.rtl-sdr.com/about-rtl-sdr/ (accessed May 21, 2019).

V-Dipole Antenna / Prototype 01

The first antenna constructed was a V-Dipole[8] for 137 to 138 MHz, which is the spectrum that weather satellites[9] transmit on. There are many variations of this design using various materials within the Radio amateur community. My intention with the design was to emphasize the handmade character of the antenna, thus I focus on using mainly readily available materials. Bent coat hangers are used in place of the two aluminum rods, and mounted with a terminal strip at a 120-degree angle on a wooden pole (see figure 2). Most radio amateurs thrive for perfection and slick designs. The intention of the antenna design is to gain a distance from the technical perfection and accuracy of the object, to shape it as an almost rudimentary tool part of a personal ritual, that is stripped off the techno-fetishism embedded in radio communities. The form and material primitivism are a way to create a connection to the impulsive and improvised rituals of ghost hunters, another niche community using manipulated FM radios as their tool to communicate with the paranormal. With this antenna, I was able to successfully receive signals from the NOAA[10] satellites 15, 18 and 19.

These weather satellites orbit in a Low Earth Orbit 850 km from the earth and use an automatic picture transmission[11] to send analog image data continuously back to Earth. The signal transmission is frequency modulated onto a carrier frequency around 137 MHz and contains telemetry information, synchronization pulses, and a minute marker. The data is used for weather and climate predictions as well as to create global images of clouds and is available for weather forecasters worldwide. Many radio amateurs build their own basic satellite ground stations for tracking those satellites and receiving their broadcasts, as well as sharing their construction

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[8] The design for this initial model is based on the work of a radio amateur (Adam 9A4QV) who published an instruction manual on his blog: http://lna4all.blogspot.com/2017/02/diy-137-mhz-wx-sat-v-dipole-antenna.html (accessed June 21, 2018)

[9] general description of weather satellites: how many are there, what kind of signals to they emit etc.

[10] National Oceanic and Atmospheric Administration

[11] Automatic picture transmission (APT) was first developed for the Nimbus 1 satellite and launched on August 28 1964.
see: https://web.archive.org/web/20070802041925/http://grin.hq.nasa.gov/ABSTRACTS/GPN-2003-00026.html (accessed March 2, 2018)

plans. Since the process is elaborately documented by the community it provides a good starting point for further accumulation of knowledge on signal transmission, as well as demodulation methods and antenna construction. Thus the research initially focused on receiving weather satellites as a method of getting acquainted with this area of radio technology, as well as enabling me to get into other forms of reception and transmission techniques as described in the following chapters. Therefore, in the course of several months, various basic tests and studies in signal reception and demodulation methods were conducted.

After close examination of the signals, what stood out were the very prominent pulses that characterized the acoustic quality of the sound. These pulses play at 2.4kHz with harmonics appearing at 4.8kHz and 7.3kHz. A rhythm that almost sounds like a 4/4 with a beat rate of approximately 120BPM. This varies throughout the reception of the satellite as an effect of the Doppler shift caused by the satellite's movement. The satellite is in constant motion and as it moves towards the observer the frequency of the signal increases and decreases as he is moving away. If the reception of the signal is not perfect, for example, if the antenna is not placed correctly or the satellite is too far away, the signal gets distorted, which makes the elements in the offbeat sound similar to an 8-bit hi-hat. The method of misaligning the antenna can lead to interesting sonic results, this method of distorting the signal is incorporated in my performance practice.

Building the V-dipole antenna and receiving weather satellite data was a crucial foundation period for the research. The observations and evaluation from the period lead to several structural conclusions on the further development of the research. The repository of recorded satellites proved to be a material that despite its qualities, lacked overall variety, therefore a search for more layered transmission was initiated in the further research process. The physical limitations of the antenna construction provided one one hand a wide scope of coverage, but at the same time this immobility and precision in pole orientation created a static situation that prevented the performer to interact with his/her toolkit once it had been set up. That conclusion led the research to turn towards possibilities for a handheld as well as mobile antenna development.

Dual Band YAGI Antenna / Prototype 02

In an attempt to attain a wider range of frequencies and portability a Dual band Yagi antenna (see figure 3) tuned between 144 to 146 MHz and 400 to 470 MHz (2m and 70cm bands) was constructed. The Yagi - which was based on a design by Radio amateur WB5CXC - is a directional antenna constructed with the intention to function as a hand-held tool, enabling manual tracking or following signals as they pass by. The design consists of copper rod elements mounted on a wooden bar and grip tape covers the bottom of the wooden bar to put more attention on mobility and its function as a hand-held antenna. With this antenna reception was made possible of a wide variety of signal transmissions like various aircraft communication, the Russian weather satellite Meteor-m2, and several unknown signals. Even though I was not able to receive other earth orbiting objects than weather satellites, the signal of the Meteor-m2 was a crucial point, as it made tangible the fact that digital transmission is an encoded bit stream and thus one can barely distinguish it from actual noise you would hear with a radio receiver. The recordings led to the observation that the radio noise shares acoustic qualities with pink noise, less higher frequencies and rumbling in the lower frequencies. The frequencies of the Meteor-m2 signal - like white noise - are equally distributed throughout the frequency spectrum.

These digital signals have to be demodulated with a special plug-in for the SDR that translated the noise into data but unfortunately does not output any audio. This feature seems to have been left out by the developer, since most of the radio amateur community is interested in the data but not in the acoustic qualities of the signal itself. So far digital signals had been a dead end but had not been totally discarded and may be revisited in a later stage of this research.

Pirates of the Ionosphere

After delving deeper and deeper through the websites of radio amateurs, “satellitenwelt.de” surfaced. The website is an archive specialized in satellite communication (SATCOM) and documents every known frequency and signal of UHF satellites (Ultra High Frequency). These technical instruments are in a geostationary[12] orbit 36000 km from earth and mostly used by the U.S. military and NATO. The satellites are part of a satellite network and are used for tactical data and voice radio communication. The archive led to an important development of the strategies of reception, since learning about their positions, frequencies and what antennas to use was crucial information. Consequently, I decided to build another YAGI (see figure 4, 5) antenna tuned to 250 MHz (see figure 1.6), the operation frequency of the aforementioned satellites.

Pointing the second build YAGI antenna in the direction of the equator for the first time is astonishing, suddenly a multitude of signals appear one after another, each of them a different satellite transponder (see figure 6). Most of those signals are audible as noise. This soft noise resembles a hissing speaker when no signal is applied. According to the database, the military keep the transponders[13] constantly active due to tactical reasons. During these receptions one signal stands out as particularly intriguing, in the spectrum it appears different then the others. Tuning into it, in an instant a foreign voice becomes audible. The signal is clear so I can identify that the man speaks brazilian. He is playing music, speaking loudly and is seemingly not sober. His tone and attitude discard the possibility of him being military personnel, but most likely a satellite radio pirate[14].

[12] A geostationary orbit is a circular orbit above the equator following the Earth’s rotation
“geostationary”. oxforddictionaries Oxford University Press. https://en.oxforddictionaries.com/definition/geostationary (accessed May 22, 2019)

[13] A device used in satellite communication for receiving a radio signal and automatically transmitting a signal.
“transponder”. oxforddictionaries Oxford University Press. https://en.oxforddictionaries.com/definition/transponder (accessed May 22, 2019)

[14] A satellite radio pirate is that broadcasts without a valid license. Wired, “The great brazilian SAT-HACK Crackdown”, wired.com.
https://www.wired.com/2009/04/fleetcom/ (accessed June 21, 2018)

The radio pirates are individuals who illegally exploit these satellites as their private worldwide CB-Radio to communicate with each other. Due to the age of most of those satellites (some have been launched in the 1970s) the communication channel is not encrypted. The satellites are not able to identify intended or unintended signals, therefore the transponder is open and automatically forwards the signals back to earth. With only basic antennas and slight adjustments to their mobile radio equipment the pirates use this illegal backdoor in their favor. Many of the satellite radio pirates are truck drivers in rural areas without cell phone reception, apparently also drug cartels and other criminal organizations use these channels for communication as the article mentions. The satellites offer better range and audio quality than legal radio amateur frequencies like shortwave. Besides the Brazilian radio pirates, in the reception I pick up Russian and Spanish speaking pirates that also operate on those frequencies, as I later discovered through my recordings. The radio pirates are a very reliable and varied sound source due to their constant activity. Their presence in the æther appears almost perpetual and thus is their appearance in my recordings. It seems like their voices have taken over the satellites, as during the course of the research I do not intercept a single military transmission. The nature of their communication is organic, they use their voices in a free, informal manner, often play music, laugh and sometimes even experiment with audio feedback. (refer to p. 23). In the incoming signal the space of transmission is often very noticeable.

Ghost Satellites

Tracking satellite radio pirates raised the question if there were other abandoned or hijacked satellites in orbit. The research blogs and websites of radio amateurs and radio enthusiasts are a valuable source of information. Many of those privately run archives collect and publish data about satellites that is generally not publicly shared by governments or space organizations. These archives often also include sound recordings that provide a reference, when identifying the satellites. A particularly valuable repository is that of the radio amateur named “happysat”. He meticulously documented and captured almost every dead satellite that is still in orbit on his website. These satellites, also called Ghost satellites, are space debris, malfunctioning objects floating in space with no utility value.

According to the latest reports[15] of the ESA[16] Space Debris Office about 5450 rockets have launched into space and placed almost 9000 satellites into Earth orbit since 1957. About 5000 of these satellites are still orbiting earth and approximately 1950 are still functioning. Since the start of Sputnik 1 all these missions leave space junk behind and it has been accumulating ever since. The ESA estimates that approximately 130 million objects are currently in orbit. The debris differs from the size of a rocket body to smaller than one millimeter and are orbiting Earth with up to 36000 km/h. They frequently collide with one another breaking into smaller and smaller parts. These small objects often cause harm to operational satellites or the International Space Station, and also pose dangers for contemporary space explorations, since it is getting more difficult to navigate through the cloud of space debris. And with the current plans of SpaceX, Amazon and Facebook to each send thousands of new satellites into Low earth orbit for their satellite internet networks, the amount of space debris will grow substantially.

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[15] https://www.esa.int/Our_Activities/Space_Safety/Space_Debris/Space_debris_by_the_numbers

[16] The European Space Agency

The following section will discuss two of the ghost satellites:

LES-1

The LES-1 was designed and built by the MIT to conduct experiments in satellite communication. It was launched on February 11th 1965, but failed to reach its intended orbit due to miswiring of the circuitry. The satellite remained tumbling in a circular orbit and ceased transmitting in 1967. In 2012, 47 years after its launch, a radio amateur from North Cornwall in England picked up a ghostly signal and that he later identified as the LES-1. Phil Williams G3YPQ suggested that the onboard batteries corroded causing a short circuit and therefore the transmitter on 237mHz to start up when the satellite's solar panels are in direct sunlight. As a result of the satellite's peculiar motion, the signal that appears to be the transmitter's carrier frequency, slowly fades in and out in a four-second cycle, like a singing ghost. Listening to the signal for the first time is fascinating, an eerie signal from an early remnant of space exploration and communication that whispers from the ionosphere tumbling through space, slowly rising from the noise after nearly a half-a-century. (see figure 7)

An event like this provides abundant material for conspiracy theorists. Many fake news websites and Youtube channels cover the satellite's history and construct narratives around it. They all refer to a theory that claims that the satellite was hijacked by an alien lifeform. As with all fake news it is hard to track the original source of the theory, since it often no longer exists or is diluted in a network of fake news websites. Conspiracy theories, lurking within the realm of radio and electro magnetics is a topic that informs and enhances both the research and performance, providing material and narratives that weave into both the amateur community and the ghost hunters. In a continuation of the project, I plan to revisit this vast field, that needs extensive research and could not be conducted in depth during this phase project.

The following quotes are extracted from some of the fake news stories and Youtube videos about the LES-1:

Abandoned in space in 1967, a US satellite has started transmitting again[17]

After learning that a satellite that's been silent for decades has suddenly started sending out new signals you may, of course, suspect that the device has been hijacked by aliens, now trying to communicate with Earth. Perhaps they're warning us that they are planning an invasion!

Lost In Space for 50 Years Dead Satellite Starts Sending Messages[18]

Recently, the LES1 which has been missing for around 50 years, has mysteriously began to transmit strange signals. Some people think the satellite was hijacked by an alien civilization that went on to transmit signals in order to establish contact with humanity.

DEAD SATELLITE STARTS SENDING CREEPY SIGNALS AFTER 50 YEARS [19]

While Phil says its remarkable to think that electronics built nearly 50 years ago, 12 years before Voyager 1, and long before microprocessors and integrated circuits, is still capable of working in the hostile environs of space. Others immediately think of the movie Independence Day with Will Smith and Jeff Goldblum in which Aliens hijacked Earth's satellites to use them to coordinate their attacks. [...] Alien conspiracy people, however, are quick to point out that in the movie, the satellite signal code was a repeating signal that once ended would signal the beginning of the attack. And that this signal is doing just that, repeating every 4 seconds. Others think there could be aliens trying to communicate with us through our own satellites.


Jose Francisco Medeiros 1 year ago (edited)
I would of thought the Alien mother ship is now close enough to use our satellites against us, haven't you watched the movie, 'Independence Day' yet? :-)

[17] Brad Smithfield. "Abandoned in space in 1967, a US satellite has started transmitting again." thevintagenews.com. (October 2016): https://www.thevintagenews.com/2016/10/31/abandoned-in-space-in-1967-a-us-satellite-has-started-transmitting-again/ (accessed May 21, 2019).

[18] Mystery History. "Lost In Space for 50 Years Dead Satellite Starts Sending Messages" YouTube video, 2:17. March 21, 2019. https://youtu.be/YnfMLTPqdKI

[19] Michael Ross. "DEAD SATELLITE STARTS SENDING CREEPY SIGNALS AFTER 50 YEARS." YouTube video, 4:25. March 21, 2019. https://youtu.be/Cz3ay8ZT620

The satellites carrier frequency is tuned to approximately 1000Hz and gliding to 500Hz while being out of the sun. Due to the Doppler effect the frequency of the radio receiver has to be adjusted constantly to keep the carrier frequency stable. If this alteration is not followed, a peculiar effect occurs, as the carrier frequency slowly decreases. In the course of eight cycles it will detune in the following steps (in Hz): 960/533, 922/479, 860/426, 816/375, 760/326, 716/275, 666/224, 616/175. This phenomena has similar audible qualities to going down a musical scale.

When analysing the recordings of the LES-1 an irregularity in the spinning cycles in each of my recordings is noticeable. In the documentation of multiple radio amateurs the cycles are described as four seconds long. The cycles of my two successful receptions are 10 and 13 seconds long. This raises the question if the rotation speed of the satellite is slowing down. My intention is to conduct further recordings to investigate this mysterious behaviour, but throughout winter and the beginning of spring the satellite's orbit and the sun cycles do not match with my position. Therefore, I hope to investigate this phenomenon at a later stage of this research.

Transit 5B-5

The Transit 5B-5 was launched on December 31 in 1964 as part of the Navy Navigation Satellite System and is one of the oldest satellites in earth orbit. The network of 27 satellites is the predecessor of GPS and the Navy used it for locating their ships and submarines. Only 19 days after it was launched, the Navy lost control over the satellite. The navigation transmitter shut down for unknown reasons and the satellite stopped responding to command signals. But the transmitter continued functioning and has been broadcasting telemetry data back to earth ever since. The satellite only starts transmitting in direct sunlight, if the solar panels generate enough electricity, presumably its batteries are not functioning anymore after so many years.

The Transit5b-5 can be regarded as the "grail" of my signal hunts. It took six month of persistent tracking to finally capture it. This is due to the fact that when I first learned about its existence in autumn 2018, daylight got continuously shorter and throughout winter the solar-panels of Transit 5B-5 could not generate enough electricity to power the satellite. Also the satellite's orbit did not align with Rotterdam during that time, it was only passing sporadically. (see figure 8)

Since I only recently was able to receive the satellite, I could not analyse the signal in more detail at this stage of my project. It is the nature of the research. Depending on those rhythms, on nature and the satellites orbit. Many trajectories have to align in unison, it is not possible to plan these in advance.

Signal hunting

The following chapter describes in detail each of the three practices that this research branches into. Namely the signal hunting, performance practice and sonic studies.

Signal hunting is a carefully planned activity that I engage to track and capture the transmissions of specific satellites. This action involves being outdoors and demands tuning into the circadian rhythms of specific satellites intended to be received. The hunt locations in which satellites can be received, require meeting certain conditions as the signals are often very weak. Interferences from cell towers or other radio signals like WIFI networks can easily render the reception impossible. Therefore it is necessary to seek places that are outside of the city center and ideally remote from urban infrastructure. However by hunting in urban areas my presence and unusual equipment often unintentionally interrupt the routine of passersby, that then often seek conversations with me. These interventions are not planned, but as these moments arise I take the opportunity to interact with an audience in public space. To engage a dialogue with passersby creates a possibility to dive into a different social or cultural context. It informs me of a level of interest and how knowledgeable a non-audio savvy audience is. Sometimes through these encounters, a brief invisible link emerges between the satellites orbiting earth and the strangers, other times I meet people who share my interest in the practice of hunting, such as metal-detector hunters or military personnel.

The process of signal hunting often requires patience and discipline and rituality is an integral part of my research. Enacting the signal hunt as a ritual is a way to bring attention and elevate the significance of the series of actions executed during the performance. In times were everything is accelerated, taking time is a relevant undertaking. During the act of signal hunting it is important to decelerate, focus your attention and observe. Centering the attention towards active listening and channeling one's concentration on the very moment of the act, as well as practicing processes through repetition. These actions also include identifying the satellites, memorizing their sounds and characteristics. This is a constant learning process, as my recordings often sound similar but are never identical to the documented sounds in the archives of the radio amateurs. This is caused by multiple unknown factors in the reception, such as the state of the satellite, its distance and trajectory, the material of the antenna, electromagnetic interference, weather conditions, daytime or season - just to name a few. All these elements influence the transperception[20] of the satellite. The satellite will always remain a mysterious object, since we are unable to interrogate its full detail in the transient moment we are able to listen to it.

An essential part of the signal hunt is writing a reception diary, this is a way to archive my signal hunts and compile technical data about the satellite, time and location, as well as document my process and impressions of the space I am recording in. It is also a tool to train my ears to the radio transmissions. In the beginning of the research, technical data dominates my reception diaries, but the more I focus my attention and senses and tune my ears to the signals, distinct acoustic qualities become evident and the presence of the surrounding environment gains relevance.

The studies I conduct, allow a meticulous examination of the recorded satellite signals and closely discern details in the sound, which would be impossible during a live performance. My studies are an exposition of different acoustic qualities, audio signal processing methods to orient the audience to the mode of listening I have adopted over the course of this project. As with the performance, my approach is intuitive but at the same time directed towards a result in sync with my practice. This methodology allows exploring the acoustic qualities of the satellite signals with awareness of the musical result. The approach is inherently subjective, based on my personal aesthetics and can be applied to every layer of my practice.

[20] Kahn, Douglas, Earth Sound Earth Signal (Berkeley, University of California Press, 2013), 162.

Reception Diary

The following section includes an excerpt of my reception diary.

Date: 04/03/2018

Time: 17:15

Observing location: 51°56’09.0”N 4°29’47.6”E

Object name: NOAA-18 NSSDC

ID: 2005-018A

Frequency: 137.9125 MHz

Demodulation method: NFM

Antenna: V-Dipole

Trajectory: Start: 17:28 - ESE / Peak: 17:35- NE / End: 17:41 - N

Visibility: Marginal

This is the first test with the V-Dipole antenna. I am in the yard of my studio. On the satellite tracking website[21] is noted that the weather satellite NOAA-18 will be passing over Rotterdam but its visibility is only marginal, thus the reception is expected to be poor. However the construction of the antenna is finally complete and I am eager to try it. After a brief pause to evaluate whether the effort may be pointless or not, I align it from north to south and wait patiently for the satellite to appear. I carefully adjust the filters of the radio software, while staring at the screen awaiting changes the spectrum analyzer. Just as predicted, the reception of the satellite is very poor and noisy. Throughout the twenty-minute recording, the satellite is audible for just about three minutes. Then it fades away again. It is a brief encounter, but I am able to record it, it is there and I almost feel as if we made contact. This is my first successful recording!

[21] https://www.n2yo.com - provides real time tracking and pass predictions

Date: 08/03/2018

Time: 20:15

Observing location: 51°56’09.0”N 4°29’47.6”E

Object name: NOAA-19 NSSDC

ID: 2009-005A

Frequency: 137.100 MHz

Demodulation method: NFM

Antenna: V-Dipole

Trajectory: Start: 20:23 - SE / Peak: 20:30 - ENE / End: 20:37 - N

Visibility: Good

Second test with the V-dipole antenna. Visibility of NOAA-19 is expected to be good but it is very cloudy today. The reception is as some days ago very poor. Is that caused by the weather or is my antenna poorly constructed? Perhaps the material of the coat hangers I used for the rods of the antenna is not conductive enough?

Date: 14/03/2018

Time: 21:30

Observing location: 51°56’09.0”N 4°29’47.6”E

Object name: METEOR M2 NSSDC

ID: 2014-037A

Frequency: 137.100 MHz

Demodulation method: NFM

Antenna: YAGI

Trajectory: Start: 21:27 - S / Peak: 21:34 - W / End: 21:42 - NNW

Visibility: Good

First test with the new dual band YAGI antenna today. This time, the antenna is constructed from copper rods with the expectation of better reception quality, since I am a bit disappointed with the results of the V-dipole. Today the METEOR M2, a russian weather satellite is in range. I hope its signal is different from the NOAA satellites, I desperately am looking for some variety. As it starts to appear in the spectrum I am astonished, the satellite uses digital transmission. I can barely distinguish it from the actual radio noise. The plugin for the radio software I have to use does not output the decoded signal. No surprise, I guess the radio amateur community is not really interested in the acoustic qualities of the data, and did not implement this option.

Date: 05/05/2018

Time: 15:30

Observing location: 51°56’09.0”N 4°29’47.6”E

Object name: UFO F7 (USA 127)

NSSDC ID: 1996-042A

Frequency: 252.050

Demodulation method: NFM

Antenna: YAGI UHF

Trajectory: GEO

Visibility: Excellent

Recently I discovered a document listing the frequencies of many UHF SATCOM satellites. Most of them transmit around 250MHz so I had to build another YAGI antenna, to be able to receive those frequencies. Today I am testing it. The document states that the SATCOM satellites are all situated in a geostationary orbit along the equator, so my decision is to go to the Kralingse Plas, a lake next to my studio, that has perfect clear sight towards south. There are numerous people at the lake, today is a really warm day and everyone is swimming and barbequing next to me. Among this swarm of people, I set up my notebook on the grass next to the shore, tune the receiver and point the antenna towards south. I cannot believe my eyes as instantly at least eight different signals appear in the spectrum. Some of them are just noise, I read earlier that the military keeps the transponders active due to tactical reasons. But one looks like there is a lot of activity. I adjust the frequency of the receiver and suddenly a foreign voice appears. He sounds brazillian and definitely not like how I imagine military personnel behaves. He must be one of those satellite radio pirates I read about. Curious and perhaps attracted by the noise a man approaches me. He is in his swimsuit. We start a conversation that soon reveals that he works for the dutch military and has recognized the antenna from his training in radio transmission thus is wondering what I am doing here. While we talk, he pulls out his phone and swipes through some pictures of one of his field exercises. On one I see him with a military UHF antenna squatting in front of a tank. That is about all the information he provided me with, and even though I was, he definitely wasn't keen on sharing much if any information about his work. The SATCOM pirates are very active throughout the whole afternoon, I record about two hours of material and experience many sonically interesting moments. I intercept a conversation between two men, one seems to listen back to himself while transmitting creating a feedback loop. He appears to enjoy experimenting with it while slowly laughing into the microphone of this transmitter. As he notices the feedback rising he repeatedly increases the intensity of his laughter. The signal is quickly overloading resulting in screeching feedback. After this loud squeal he moves away from the microphone, the conversation continues in the distance. Around two minutes later music appears in the background, the space wherein it is played is clearly noticeable in the signal. The room sounds reverberant, images of a car repair workshop come to my mind. The higher frequencies of the signal get increasingly more distorted and the music disappears in the radio noise. I think he lost connection.

Date: 14/05/2018

Time: 18:30

Observing location: 51°56’09.0”N 4°29’47.6”E

Object name: UFO F7 (USA 127)

NSSDC ID: 1996-042A

Frequency: 252.050

Demodulation method: NFM

Antenna: YAGI UHF

Trajectory: GEO

Visibility: Excellent

A bizarre experience. I did some minor adjustments to the UHF YAGI antenna earlier, making it more sturdy and changing the connector to BNC. After finalizing the upgrade, I want to test it in front of my studio, to confirm that I have connected the new connector correctly. After setting up quickly I start scanning the sky for signals. At first I do not find any satellite transmissions, but then something odd happens. While pointing the antenna towards the building, the signals suddenly start to appear in the spectrum. It is as if the walls are emitting the sounds. I take my setup to the position at the wall where I speculate the emissions are coming from and try scanning from there. Perhaps these are reflections? Scanning the sky from there in all directions, and nothing to be found.

Date: 20/05/2018

Time: 11:00

Observing location: 51°56'09.0"N 4°29'47.6"E

Object name: unknown

NSSDC ID: unknown

Frequency: 10.7 GHz

Demodulation method:

Antenna: Satellite Dish

Trajectory: unknown

Visibility: unknown

An abandoned satellite dish catches my attention on the street. I wonder if I could receive any signal with it. After looking into satellite dish signal reception, the only information that surfaces is how to properly align the dish for watching Satellite TV (of course). That does not discourage me and I still attempt to connect it up to my RTL-SDR dongle and scan the spectrum, alas with no success. Working with those kind of frequencies is a completely different realm. A realm I might revisit at a later stage of this research.

Date: 15/09/2018

Time: 12:00

Observing location: 52°10’40.7”N 5°49’04.9”E

Object name: Skynet 4E, SYNCOM 2

NSSDC ID: 1999-009B, 1963-031A

Frequency: 254.130, 255.550

Demodulation method: NFM

Antenna: YAGI

Trajectory: GEO

Visibility: Excellent

Today we are on a field-trip, me and a group of radio enthusiast friends. We are visiting an old shortwave radio transmitter. In the 20th century Radio Kootwijk was an important wireless connection point between the Netherlands and its colony the Dutch East Indies. Due to the development of new technologies like satellite communication, Radio Kootwijk lost its relevance as an overseas radio communication facility and was closed in 1966 and is now designated as a heritage monument located in a national park. The road from the highway leads through conifer trees and it somehow feels like entering a Radio Quiet Zone.[22] The building is located in a wide open moorland complete with drift sand outcrops and surrounded by forest. In the middle stands Radio Kootwijk’s imposing transmitting station. We park, take all our antennas and radio equipment with us and walk towards the building. The path to the station goes in a perfectly straight line terminating at the building entrance. It makes it feel like I am approaching a temple. The courtyard is walled off, we enter between the two story houses. After taking two steps down

[22] A Radio Quiet Zone is a restricted area protected from radio interference

we stand in front of the reflecting pool, we have to walk around it to reach the entrance of the building. The ornament on top of the doorway of the concrete tower , a big face paired with two figures holding their ears on top of the lettering "RADIO STATION", almost looks like the totem of a sacred radio god, a lord ruling during the golden age of radio. Sadly the building is completely empty and all the equipment is gone, the only relics left are some old light bulbs I can see lying on the window sill. After exploring the area around the building, we decide to find a quiet spot along to set up our antennas and attempt to hunt some signals. We follow a hiking path that leads us to a forest glade with clear vision to the radio station. I tune into the UHF frequencies that the Satellite radio pirates use and start recording. At first there is no signal at all. I find that very surprising since we are quite far away from any interference. But within a minute the satellite transponders start to appear in the spectrum analyzer and the pirates appear, active as always. It feels like the antenna needs some time to warm up to be receptive for radio signals. We spent the whole afternoon at this spot, among the trees, lying in the sun, listening to various signals. Jad, a fellow radio researcher, has brought his shortwave radio and scans through the stations, that occasionally erupt into bursts of morse code and voices of radio amateurs. As our signals blend into each other, the noises of a distant military field exercise and the sounds of the natural environment also begin to merge with the radiophonic ambiance. This shapes a vast soundscape at this historically-charged location. It feels uncanny and at the same time poetic, mixing shortwave signals with the SATCOM transmissions that have brought this building to obsolescence.

Date: 28/09/2018

Time: 19:15

Observing location: 51°56’20.8”N 4°30’30.1”E

Object name: LES-1

NSSDC ID: 1965-008C

Frequency: 237.00 mHz VHF

Demodulation method: USB

Antenna: YAGI

Trajectory: Start: 19:20 - SW / Peak: 19:35 - S / End: 19:50 - E

Visibility: Marginal

I have been following this satellite for some weeks now, but its orbit is never close enough to receive its signal. On the 28th the visibility is only marginal but I still attempt to capture it. With my YAGI antenna packed, I go to a location in the vicinity of my studio with a good view and no obstacles from east to southwest. I tune my SDR to 237 MHz and patiently await. Thirty long minutes pass before the signal finally appears. I try scanning the frequency spectrum and different filters but the satellite is not in range. According to the calculations of my satellite tracker it will change its course of the following days.

Date: 06/10/2018

Time: 19:30

Observing location: 51°56’20.8”N 4°30’30.1”E

Object name: LES-1

NSSDC ID: 1965-008C

Frequency: 237.00 mHz VHF

Demodulation method: USB

Antenna: YAGI

Trajectory: Start: 19:38 - SW / Peak: 19:56 - S / End: 20:14 - E

Visibility: Excellent

A week after my first try, the satellite tracker expects an excellent flyby, following the border between Germany and The Netherlands. Shortly after sundown I go back to the lake, this time it is cloudy and there is light rain, so I set up inside a little hut on a children playground right next to last week’s location. Again I wait patiently pointing my antenna to the sky for the signal to appear. I cannot find the signal at first, there is an interference overlapping with the exact same frequency as the LES-1. As the satellite’s path reaches its peak, the signal softly appears on the waterfall, I adjust the filter and there it is, my first successful catch of a ghost satellite. As a result of the satellite’s peculiar motion the signal slowly fades in and out in a four-second cycle. As the LES-1 passes by, its signal slowly dies away and simultaneously pitches down due to the Doppler shift, therefore I have to constantly adjust the filter of the software defined radio.

Date: 13/10/2018

Time: 19:30

Observing location: 51°56’20.8”N 4°30’30.1”E

Object name: LES-1

NSSDC ID: 1965-008C

Frequency: 237.00 mHz VHF

Demodulation method: USB

Antenna: YAGI

Trajectory: Start: 19:10 - SW / Peak: 19:25 - S / End: 19:40 - E

Visibility: Good

As I hunt the LES-1 at the lake today I have a peculiar encounter with a detectorist. We both seem intrigued by each other and attempt communicating that my Dutch vocabulary seems too limited to conduct, while simultaneously inspecting each others tools. He tells me he is hunting for jewelry on the beach of the lake. All those lost little things silently buried in the sand , that are just impossible to find, that are impossible to see. He seeks below the surface and I seek above the atmosphere.

Date: 11/11/2018

Time: 18:15

Observing location: 51°56’20.8”N 4°30’30.1”E

Object name: LES-1

NSSDC ID: 1965-008C

Frequency: 237.00 mHz VHF

Demodulation method: USB

Antenna: YAGI

Trajectory: Start: 18:40 - SW / Peak: 18:55 - S / End: 19:08 - E

Visibility: Good

Today I miss my opportunity. I return to the lake again, while setting up onsite I realize I have forgotten to take the RTL-SDR dongle.

Date: 26/11/2018

Time: 08:00

Observing location: 51°56’20.8”N 4°30’30.1”E

Object name: TRANSIT 5B-5

NSSDC ID: 1964-083D

Frequency: 136.658

Demodulation method: USB

Antenna: YAGI

Trajectory: Start: 08:15 - SSE / Peak: 08:24 - ENE / End: 08:32 - N

Visibility: Good

I read about another ghost satellite, Transit 5b-5. Radio amateurs call it “the singing satellite”. I see it will orbit Rotterdam very closely. I wake up early and bike to the lake. Dawn starts setting in just when I arrive. It is freezing cold this morning. I hope that the satellite will catch enough sunlight to turn on and start transmitting. I start recording and search the sky thoroughly with the antenna, but after seventeen minutes of nothing on the spectrum analyzer I give up. It had passed Rotterdam silently.

Date: 26/12/2018

Time: 17:00

Observing location: 48°46’41.8”N 15°49’08.3”E

Object name: TRANSIT 5B-5

NSSDC ID: 1964-083D

Frequency: 136.658

Demodulation method: USB

Antenna: YAGI

Trajectory: Start: 17:05 - SSE / Peak: 17:14 - ENE / End: 17:22 - N

Visibility: Good

On the second Christmas day I am visiting my family in my father’s hometown Weitersfeld in Austria. It is sub-zero and windy outside and the sun went down already about an hour ago, but I do hope that the solar panels had charged the satellite’s batteries just enough during the day, to be able to transmit. My cousin joins me and we climb up a hill next to my grandparents’ house where we often played as children. We do not talk. I set up the antenna on a wood pile and try moving and angling the antenna in every possible position. Sadly, it is silent again.

Date: 20/01/2019

Time: 17:45

Observing location: 51°56’11.1”N 4°29’15.8”E

Object name: TRANSIT 5B-5

NSSDC ID: 1964-083D

Frequency: 136.658

Demodulation method: USB

Antenna: YAGI

Trajectory: Start: 17:46 - NNW / Peak: 17:56 - WNW / End: 18:04 - WSW

Visibility: Good

Nothing…The sun is not in my favor at the moment, tomorrow the satellite will pass by earlier.

Date: 21/01/2019

Time: 16:15

Observing location: 51°56’11.1”N 4°29’15.8”E

Object name: TRANSIT 5B-5

NSSDC ID: 1964-083D

Frequency: 136.658

Demodulation method: USB

Antenna: YAGI

Trajectory: Start: 16:46 - NNW / Peak: 16:56 - WNW / End: 17:04 - WSW

Visibility: Good

Today Tony and Jad, two fellow researchers, join me on my hunt for the Transit 5B-5. We set up our equipment on a tree stump at a location in the north-east side of Rotterdam. Since we arrive earlier than the expected passing of the Transit 5B-5, I tune into the SATCOM frequencies and introduce Tony to the satellite radio pirates. I deliberately try to use an incorrect demodulation method on their voices and also detuning the frequency and that leads to some unexpected and satisfying results. The voices are not recognizable anymore, the sound resembles a really heavy digital distortion, producing glitch-like rhythms. These pulses suddenly blend with weeping sounds of a coot in the distance. The poor coot had broken its leg. Jad tries to help it, but it limps away in pain. Shortly it is time for the ghost satellite to appear, I quickly readjust the receiver and the antenna and we wait for it to rise over the horizon. It quickly gets dark, I hope the satellite can receive enough sunlight. As I move the antenna along the satellites trajectory I pickup only noise and interferences. For a glimpse I think I can hear the satellite but soon I realize it is probably the cell tower on top of the apartment block next to us. If the satellite is still transmitting it would not be strong enough to penetrate through the tower’s signal. Again no luck today.

Date: 26/01/2019

Time: 17:00

Observing location: 51°56’11.1”N 4°29’15.8”E

Object name: TRANSIT 5B-5

NSSDC ID: 1964-083D

Frequency: 136.658

Demodulation method: USB

Antenna: YAGI

Trajectory: Start: 17:16 - NNW / Peak: 17:26 - WNW / End: 17:34 - WSW

Visability: Good

I notice a pattern, it is the 26th again. Browsing back through my notes, it is the third time I am looking for the Transit 5B-5 on the 26th . *All good things come in threes.* Not today though...

Date: 24/02/2019

Time: 07:55

Observing location: 51°56’11.1”N 4°29’15.8”E

Object name: TRANSIT 5B-5

NSSDC ID: 1964-083D

Frequency: 136.658

Demodulation method: USB

Antenna: YAGI

Trajectory: Start: 08:15 - SSE / Peak: 08:24 - ENE / End: 08:32 - N

Visibility: Good

It is still dark as I go out. According to the satellite tracker today is the last possibility to hunt the satellite for a long period to follow. The prediction for the next three weeks shows no passages close to Rotterdam. As I arrive at the lake it starts raining. I quickly find shelter underneath the slide at the playground and initialize the radio software. No sign of the Transit 5B-5, I think there is still not enough sunlight for the satellite to power on. The only signals I find around the satellite’s frequency are interferences and short bursts of air traffic as well as a periodic signal next to it. The radio communication between the airport and the aircraft is operating in the same frequency band as the satellite. I assume the periodic signal is from the ADS-B[23] Signal, a surveillance technology used to track an aircraft's position.

[23] Automatic dependent surveillance—broadcast

Date: 19/03/2019

Time: 15:00

Observing location: 51°56’20.8”N 4°30’30.1”E

Object name: Skynet 4E, SYNCOM 2

NSSDC ID: 1999-009B, 1963-031A

Frequency: 254.130, 255.550 MHz

Demodulation method: NFM

Antenna: YAGI

Trajectory: GEO

Visibility: Good

After two weeks of uninterrupted rain it finally feels a little like spring. Lured by the sun I go to the lake to test my performance setup. As well as to record and film at the lake. I take both of my cameras today to film the environment. I have an idea to shoot side by side videos and to juxtapose them later in editing software. The clouds are so ornamental today and the full spectrum camera (a modified camera recently purchased online from a member of the ghost hunter community, see figure 9) exposes unseen layers in the watery vapor mass. In combination with sound, this could serve as an analogy to my method of applying filters to the radio signal to unveil elements hidden in the noise. A group of joggers pass by like a cloud of voices. At the end of the recording session a woman with three dogs approaches me. She is curious about all the equipment I have surrounded myself with and wants to know more about what I am doing. I give her a brief introduction of my research and the signal she is hearing. “wow! I have only seen this in the movies” she exclaims.

Date: 24/05/2019

Time: 21:15

Observing location: 51° 56' 11.204"N 4° 30' 31.383"E

Object name: TRANSIT 5B-5

NSSDC ID: 1964-083D

Frequency: 136.650

Demodulation method: USB

Antenna: YAGI

Trajectory: Start: 21:29 - SSE / Peak: 21:38 - E / End: 21:46 - N

Visibility: Good

The days are slowly getting longer and the sun's cycles are syncing with the satellite's circadian rhythm. The past months it had been passing Rotterdam only during night. As the daylight, I hope my chances of receiving it are also increasing. I have to admit I start losing faith, I am on the hunt for half a year now … maybe it fell silent forever? After 55 years of activity that seems like a possibility, there is no way to check. The coming days it will pass during sunset. I take my tools to the lake and set up at a sunny spot on the pier. It is a clear day, not even a single cloud. As the sun slowly goes down I eagerly point the antenna towards the horizon. The following seventeen minutes I slowly track the satellite's trajectory from south-southeast via east to north. While I continuously tune the receiver and adjust its filter I hear nothing but noise. Towards the end of the reception I suddenly spot a flickering light in the distance. I first think it might be Polaris - the North Star - but then I notice it is moving. The spot is following the same path as the Transit 5B-5 and disappears behind the trees at the same time as the satellite tracker calculated. Did I just see it?! I pack my tools and rush back to my studio. I want to dissect the recording in the DAW. I relisten to the whole reception and zoom into the spectrum analyzer. Near the end of the recording I notice a curved line, it is only two seconds long and looks like an extremely distorted sine wave. The signal is very faint but it might be the satellite's carrier frequency!

Date: 25/05/2019

Time: 22:00

Observing location: 51° 56' 15.487"N 4° 31' 31.121"E

Object name: TRANSIT 5B-5

NSSDC ID: 1964-083D

Frequency: 136.650

Demodulation method: USB

Antenna: YAGI

Trajectory: Start: 22:15 - S / Peak: 22:24 - W / End: 22:33 - N

Visibility: Excellent

Elevated by yesterday's discovery I head out to the lake again. The satellite tracker predicts an excellent pass over Rotterdam today. I tune the receiver to the satellites frequency and point the antenna towards south. Halfway through the pass and without a trace of the satellite, I want to change some settings of the radio receiver. Since I do not have a tripod with me I just lean the antenna straight up against my bicycle. And I cannot believe my eyes, the signal appears in the spectrum. I adjust the filter bandwidth and there it is - the signal of the satellite. The carrier frequency sounds like the satellite is howling, similar to an oscillator with a slow LFO modulating its frequency. 10 kHz next to the carrier frequency I can hear the telemetric data. It is singing a random melody that reminds me a bit of a synthesised birdsong. In eight minutes it slowly fades away as it disappears beyond the horizon. Unbelievable after six months of persistence I have finally captured it!

Performing the Æther

Performance Varia

The first Signal hunting performance took place at Varia (see figure 10) – the center for everyday technology (footnote and link) - in Rotterdam as part of the event series “Century 21 Calling”. The series of screenings of archival industrial films, corporate infomercials, TV reports, and historical documentaries are organized and curated by my friend and colleague Thomas Walskaar. The edition in October 2018 focused on the development of satellite communications starting from the late 1950s to our present day.

The performance setup was centered around my notebook with two RTL-SDR receivers and antennas, as well as my modular synthesizer for further transformation of the incoming material. I selected a stationary omnidirectional turnstile as well as a YAGI antenna to manually track the signal. On the notebook, the radio software was initialized twice to receive with both USB dongles at the same time and tune into different signals. The audio output from SDRsharp was routed into the modular synthesizer for processing. The selected modules of my modular synthesizer were based on processing ideas I worked out during prior rehearsals for the performance. The assembly consisted of two Voltage-controlled filters (VCF), multiple Voltage-Controlled Amplifiers (VCA), function generators and Low-frequency oscillators (LFO), two Voltage-controlled oscillators (VCO), a granular texture synthesizer and a sample and hold.

The initial plan was to use a four loudspeaker sound system. The heart of this setup was a prepared satellite dish in front of me. I replaced the LNB[24] with a loudspeaker pointing at the center and attached a transducer on the metal surface of the parabolic antenna. In addition, two

[24] Low-noise block downconverter

monitor speakers were placed in the back of my setup to add some low end to the audio. The processed audio could either be routed back into the computer and via an external soundcard to the satellite dish or sent directly from the modular synthesizer through an audio mixer to the monitor speakers.

The setup was in front of Varia on a little square, and after the screening came to an end, Thomas led the audience to the performance location. All my equipment was arranged on the pavement creating an atmosphere of spontaneity. After a brief introduction about my practice and the research on satellite hunting, the performance started with adjusting both of the antennas and starting the radios. I tuned both of the receivers to around 252 MHz. Immediately signals of the radio pirates started appearing in the spectrum analyzer. After a couple of minutes of speech, one of them started playing salsa music.

Even though the performance was successful according to the responses received from the audience, the setup was too complicated. Trying to fit all the ideas that occurred during the research process into the performance made it rather difficult to maneuver through the system. Regardless I had been practicing with the setup before the event, a rehearsal cannot be compared to a live performance. It was impossible to exert control over the two radios, the modular synthesizer, as well as an audio mixer, and react to the incoming signal. To tune the radios I had to switch between different application windows. Also, the modular setup was not pre-patched, therefore I was overwhelmed by the complexity of my setup. As a result of this, I discarded most of my ideas during the performance concentrated on only one radio receiver and focused just on filtering and layering the incoming transmissions.

Conclusion

To conclude, I believe that the screening and performance complimented each other quite well. Thomas selected some films based on the satellites I was receiving during the performance in his program. The presented footage introduced the context around satellite communication and informed the audience about some of the satellites histories. Therefore the audience was already in the right mindset for my performance, making the signals of this otherwise very abstract objects more tangible and graspable. Consequently, this made it clear that including stories and information about the satellite and signal reception needed to be an integral part of the performance. This not only promotes active listening but also lets the audience become part of the hunt.

It became evident that my setup was too bulky and had to be revised. I needed to reduce the equipment to a compact unit that would allow me to be more mobile and off the power grid. The instrument had to be simplified, functions pre-patched and processes prepared, to make the synthesizer overall more playable.

Performance Kugelmugel

In the beginning of May 2019, the second Performance of "drowning in æther" was shown in the Republic of Kugelmugel in Vienna as part of the event series "Advanced Obstacles" organized by nothing more[25]. This association of artists and researchers shares an interest in FLOSS oriented art practices, collaboration and critique on technology. Joseph Knierzinger, a friend and member of nothing more, organized an evening focused on works with and around radio waves and invited me to present my current research.

The Kugelmugel itself is an impressive wooden building in the shape of a sphere (see figure 11), built by the artist Edwin Lipburger in the late 1970s. After disputes over building permits for a ball-shaped house with the Austrian government, Lipburger announced the state of Kugelmugel and was arrested and sentenced to jail for 10 weeks. The fictitious micronation has over 650 non-residents and is located in the Viennese Prater, an amusement park close to the city center.

The plan was to gather the audience at the Kugelmugel and then perform in front of the building, on the lawn in between the sphere and the trees. A location free of obstacles that provides clear access to the skyline and with the spherical building in the background, the audience and I would become the satellites that orbit the planet Kugelmugel. This evening three satellites were passing Vienna within half an hour, and by chance, the times corresponded with the performance.

After arriving at the Kugelmugel in the afternoon before the performance and conducting some basic reception tests, the first obstacle of the performance appeared. Even though the location is in a park and not closely surrounded by houses, it is still in the city center and thus barely possible to receive any signal. The spectrum of the radio software was full of noise and interferences. Signals of cell towers, WIFI signals, and many other radio waves of the urban infrastructure were drowning the satellite transmissions. It is also probable that the motors of nearby roller coasters from the amusement park created electromagnetic waves that interfered

[25] https://nothingmore.work/s/in/advanced-obstacles/

with the radio receiver and antenna.
The second challenge appeared in the evening. About two hours before the performance the weather abruptly shifted, it started raining severely and the temperature dropped to 4°C, and it would not stop for the rest of the evening. Moving the performance to the interior of the Kugelmugel building, made it even more difficult to receive the satellites transmissions since the surface on the outside of the structure is coated with brass. Consequently, I needed to improvise and decided to take a different approach than what I had prepared for this evening.

During the Sonic acts festival in February 2019, I joined an inspiring lecture performance by the DJ and filmmaker Ephraim Asili. He gave insights into his cinematic practice and introduced the audience to past and current projects. Asili projected landscape footage of his latest project accompanied by snippets of his music played from a performance sampler. He talked in an informal and poetic manner about his practice, his travels, shared witty anecdotes, read passages of a book and even invited the audience to participate. All the above seamlessly intertwined and contributed to being the highlight lecture of the festival. What seemed an improvisation created a personal and intimate atmosphere between him and the listeners. Thus the audience was not only witnessing his presentation, they got involved in his thinking process and way of working. Participating in this performance made me decide to improvise with some of the elements in the way I was developing “drowning in æther”. The sudden impossibility to perform outdoors was a perfect opportunity to put this approach into practice.

The interior of the Kugelmugel is entirely wooden and the performance space is in the center of the first floor. The audience is seated on a long bench lining the full circumference of the sphere, this sitting circle creates an intimate and yet unusual scene. As mentioned above, I decided that the format of a lecture performance was ideal for this situation. I selected some of my recordings from previous satellite hunts to play back during the piece and specifically selected files from the three satellites passing above the Kugelmugel this evening. At the beginning of the performance, I introduced my research and practice, antennas and tools. I started playing the selected recordings and weaved them with narratives about satellites, their histories, as well as the experiences from my hunts and reports from my reception diaries. While fading in and out the recordings I told new stories and pointed to the audience at the moment one of these satellites was passing above us during the act. While giving the sound material room to breathe I also routed it through my modular synthesizer, improvising with the processes I had prepared.

The main signal was patched into the bandpass filter, the three separate outputs I tuned to different frequency bands and routed into three VCA's. The amplitude of the amplifiers was then modulated with LFO's with different cycle rates. This created an organically moving texture as well as a comb filtering effect since they all descend from the same sound source. I also sampled short snippets of the filtered signal and pitched it down with the help of the granular texture synthesizer, patched it through a Lowpass filter and slightly modulated the pitch of the sample, that resulted in a Doppler effect.

After the Performance, I got the chance to speak to some of the audience and receive feedback. The visitors were a diverse mix of people with various backgrounds, artists and musicians as well as some unexpected passersby that entered the Kugelmugel out of curiosity. The reception was vastly positive and the listeners I talked to greatly appreciated the fact that I included so much of the context of my research. They felt drawn into the stories and sounds. All those made it easier for them to hear the radio signals and draw links to the satellites.

Conclusion

Performing outdoors comes with a list of challenges and not only the weather becomes an important factor but also the environment and city infrastructure. The satellite signals are almost unable to break through the cloud of radio signals that occupy our cities and habitats. Finding interference-free zones becomes more and more difficult. I did not anticipate that it would be impossible to receive barely any signal in the Prater since it is a big park and the Kugelmugel is located quite far away from residential areas.

As for the weather, while hunting alone, it is easy to cope with the weather conditions. My hunting toolkit is in a waterproof case and I can be prepared with necessary rain protection. The presence of an audience though, requires thorough preparations in advance.

Even though I had to abruptly shift my plan, the obstacles gave me the opportunity and courage to try a new format that I had been considering for a few months already. Narrative and storytelling are valuable elements to include my personal observations and experience into the piece and emphasize the context of signal hunting. The outcome of the evening was very rewarding, which was enhanced by the positive reception of the audience. For the upcoming performances of this format, preparing a guiding script will be an asset in order to be more coherent with the narrative.

Sonic studies

During the course of the research I conducted several studies, these helped me to explore the inner anatomy of the signals. The studies are not only fixed media attempts but also inform the other practices of this research. Working in-depth with the satellite signals clarifies necessities for certain specific tools within the technical domain as well as strategies for sound manipulation. It also aids developing a routine in working with radio signals to memorize and identify acoustic qualities. The research demands a constant tuning and retuning of the ears to the adopted mode of listening as new signals are discovered. All elements of this research are in constant flux. This section focuses on two sonic studies essential for the development of this research.

Ghostbox study

The starting point of this study is a recording of voice transmissions created with a script[26], published by a member of the ghost hunter community, for controlling the radio software gqrx. The script turns the RTL-SDR into a ghost box, these devices are usually manipulated FM/AM-Radios that automatically seek through the radio spectrum, ghost hunters claim to use this tool for communication with the paranormal. These devices scan back and forth through the radio spectrum receiving split-second snippets of the signals. These fragments of radio waves are interpreted as spirit voices, and within the ghost hunter community are known as electronic voice phenomena (EVP). The script initially made it possible to scan frequencies within a range specified by the user, either randomly or back and forth. The steps how far the scanner would jump forward was between 50 and 500kHz. This settings worked well with FM radio stations, but since the frequencies of UHF satellites are higher the steps between the signals are much narrower. Therefore the script scarcely hit a station and just jumped over them. Thus I modified

[26] written in the programming language python

the source code of the python script to jump between a specified list of satellite frequencies.
My interest does not lie in communication with the paranormal, I utilize this method to create percussive rhythms constructed of voice and radio noise. I am interested in the border moment, when voice is barely recognizable as such but its vocal qualities and rhythmicity are still present. Often our brain attempts to interpret these unclear sounds as familiar noises and tries to reassemble them back into words as an effect of pareidolia.

The basis of this study is an excerpt of a several minute long recording of the afore described process. The script is set to jump between satellites every 62ms, this is the threshold I established were words would not be fully recognizable anymore but the snippets were not as short as clicks. As sources I primarily selected active voice transmissions of SATCOM satellites, but also included frequencies where only interferences were picked up to include some contrasting sounds. I apply random panning to spread the snippets of sound in the stereo field to exaggerate the effect of a multitude of signals. The second layer accompanying the snippets derives from the characteristics of the background texture that I had taken notice of while listening to satellite transmissions. This texture is caused by the radio noise[27], a combination of natural electromagnetic noise, man-made radio interference and the temperature of the lower atmosphere - just to name a few. In radio communication this noise is an unwanted signal and is always subject to elimination. For me this gritty texture resembles the distance the signal has traveled and the interferences that have shaped it until it reached my ear. The noise is very noticeable when the sender ceases speaking but the transmitter is still in connection with the transponder of the satellite. By applying a narrow filter in the radio software the radio noise can be exaggerated to the point it starts to resonate. I sample a short passage of these hissing texture and apply a high-pass filter at 8 kHz to remove the voices of the transmissions. To add more low end frequencies in the study, I duplicate the texture and pitche it three octaves down. A low-pass filter and a distortion effect are used to create a humming drone-like sound, imitating the subtle

[27] ITU-R. "Rec. ITU-R P.372-13" ITU-R. https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.372-13-201609-I!!PDF-E.pdf (accessed March 2, 2018)

vibrations of the materials radio waves resonate on. The combination of the layers and various methods of manipulations expose the acoustic qualities of the encountered vocal material.
This study helps to reveal characteristics in the signal I want to expose to the audience. It discloses the importance of filters in the setup as a crucial step in the development of the signal hunting toolkit. I plan some adjustments to the script, like adding the possibility of real-time tempo changes and pauses. Unfortunately I put further developments of the script on hold, as a result of moving away from the notebook. The tablet does not allow to run the python scripts and SDRtouch has no interface for external controls implemented.

Signal silence

The second study is based on a 4 minute 20 second recording of a voice transmission by a satellite radio pirate. Rhythms are rooted in language as well as in indeterminate communication by satellite radio pirates, as their conversations are performed new rhythms get created. The aim is to examine the rhythmicity of voice and transmission, the intention is to utilize temporal events of the satellite signal. The length of the piece is dictated by the duration of the pauses between the intercepted conversation. The vocal parts of the recording are removed and the noise of the silences consolidated, resulting in a total of 1 minute and 38 seconds. The extracted vocals are combined as well and loaded into a granular sample player. An envelope follower on the noise track extracts the dynamic changes of the signal and is applied to file position and grain size of the granulator. The amplitude of the silences determines the playback position as well as the size of the sample, therefore it selects fragments of the intercepted conversation, rearranging them and generating a new narrative. A rumbling drone in the low end is used to create tension between the layers. An envelope follower tracks the amplitude of the generated conversation and controls the fluctuation of the drone by changing the strength of the applied distortion effect. The three layers are interconnected and their dynamics influencing each other. The utilized parts of the intercepted conversation create an organic rhythm throughout the experiment and within the elements.

Relevant conclusions are drawn through this exercise, and useful strategies for utilizing the dynamics of the satellite signals found. The integration of the enveloper follower proves to be a necessity for the signal hunting toolkit. Effective techniques for the combination with a granular sampler can be extracted from the result.

The signal hunting toolkit

This chapter outlines the development of the signal hunting toolkit, evaluation of the past performances as well as the sonic studies that have informed the improvement of the system. In the beginning of the reception research, the main tools are the RTL-SDR dongle, a notebook and various antennas for capturing satellite signals. With a performance in mind, the intention is to consolidate the tools mentioned above with modular synthesizer and develop a compact setup for signal hunting and improvising with satellite receptions. The indeterminacy of the incoming transmissions demands active listening of the performer, applying manipulation processes and structural ideas while spontaneously reacting on the changes of the incoming signals. For example decisions like preserving acoustic qualities with sampling techniques or discarding them by changing the frequency of the radio receiver. These choices depend on personal aesthetics and are applied intuitively.

The Eurorack format as a platform for this instrument and its modularity is an important asset. It opens the possibility to exchange functions over time as the setup develops, as well as combine different modules for each specific performance. Another benefit is its ability to apply voltage control to various parameters of the system. With the concept that every signal can be treated as control voltage, even the incoming satellite receptions become potential modulation sources. Its size and the form factor as well as power consumption are also important factors in the decision-making process. As a result of the low current drain the signal hunting toolkit can be powered via a small battery pack for up to four hours, that makes an outdoor off the grid performance possible. (see figure 12)

As outlined in the previous chapter, describing the first performance at Varia, the initial setup is complicated and not intuitive to perform with. A notebook with multiple application windows, two receivers and antennas, the modular synthesizer, and an audio mixer created a fractured setup that require a lot of attention on each separate element with no coherent connections between them. This makes it impossible to focus on improvisation and sound source manipulation in order to create a consistent and uniform performance. The setup needed to be simplified and all necessary parameters needed to be easy to access. The solution is to downscale the equipment to fit into a single waterproof flight case, add and swap specific eurorack modules and integrate an audio mixer in the case. The flight case offers crucial protection for all the electronic equipment when hunting or performing outdoors, yet is very light and mobile. The size of the case is limiting the space for the maximum number of modules but this restriction is also an advantage to compile and organize a consistent sound setup.

The next step is to replace the notebook. Initially I tested the RTL-SDR with a Raspberry Pi (footnote), but the radio software was operating unstable and finding a proper portable battery-powered screen that would fit in the case was problematic. After performing positive stability and usability tests with SDRtouch for Android OS, the decision is to implement a tablet. Not only is it lighter and already battery-powered by design, but also offers easy access and control of the radio software via multi-touch control. The Android tablet is mounted on the lid, and a BNC terminal was added to attach the antenna on the side of the waterproof case. This also makes the connection more robust, since the RTL-SDR dongle can easily disconnect when the antenna is being moved during the performance.

The initial modular synthesizer consists of two VCF's, multiple VCA's, function generators and LFO's, two VCO's, a granular texture synthesizer and a sample and hold. After evaluating the first performance there is a demand to change the behaviour of the system. (see figure 13) It needs to be more playable and encourage improvisation. A performance sampler to the setup adds the advantage to emphasise acoustic qualities in the reception by live looping, or simply adds the possibility to get the performer's hands free and focus on the radio software or the antenna. The granular sampler offers controls over pitch and timbre, as well as sample length and grain size thus provides access to multiple time scales. This allows to explore sound and time of the recorded material at various levels. From looped samples of several seconds to grains of a couple of milliseconds, this enables exploring the satellite signals in great detail.

During the research it becomes evident that filters are an essential tool when working with radio waves. These signals are often very dense sound sources, and satellite transmissions often barely distinguishable from the noise of the static. Thus my method of working with satellite signals can be compared with the subtractive approach of sculpting, carefully carving the different layers of noise with multiple filters, separating elements for further processing and shaping them into a new texture. For this process I built a filter that takes one signal input and multiplies it to three independent band-pass filters (see figure 14). These filters have full control over frequency as well as bandwidth, and have separate outputs. This allows to select different frequency bands of the audio signal, I often choose to apply varying manipulations for each specific part of the frequency spectrum. The latest iteration of the signal hunting toolkit contains a total of ten variable filters, namely band pass-, low- and high pass filters.

Another addition is the integration of an envelope follower, this module allows to track the inputs amplitude and generate voltage based on the incoming signal. This voltage then can be used to control any possible parameter in the system. Within this system this method is often used to apply dynamic signals, e.g. the voices of the satellite radio pirates, on the level control of VCA’s, pitch or sample playback position of the sampler module. This method allows the voice - without being recognized as such - to function as a rhythmical element.

Conclusion

This research started with a genuine fascination for satellite transmissions. I began accumulating tools to be able to hunt the sounds emitted by those artificial objects. As time progressed, I learned to actively listen to the vast amount of signals traveling through the ionosphere, which I have been obsessed with over my last two years. This also includes identifying the satellites, memorizing their sounds and characteristics. Throughout the research the core elements of this practice as well as different strategies to approach these indeterminate signals emerged. The reception diary serves as a platform to document my signal hunts and compile data about the satellites as well as the surrounding environment. The studies enable me to refine my hearing as well as my technical performance setup. And provide me with time to examine the recorded satellite signals and closely discern the inner anatomy of the transmissions. All the aforementioned elements slowly unfold in the performance practice, that seeks to orient and immerse the audience to my mode of listening, inviting them on a journey through the æther.

I believe that I succeeded in creating a good foundation for this practice, which supports comprehending many of the important concepts of signal hunting. And I hope to see more artists developing interest in working with satellite signals and radio waves.

Many questions about these mysterious objects and their signals are impossible to answer, since we will never be able to observe a satellite in its full detail. Despite that, all unknowns only feed the imagination. At the current stage of the research the depth and complexity of the topic is revealed, there are various trajectories that I have to unfold as this research is further pursued. This paper lays the groundwork for a complex and exciting practice that extends beyond these concluding words.

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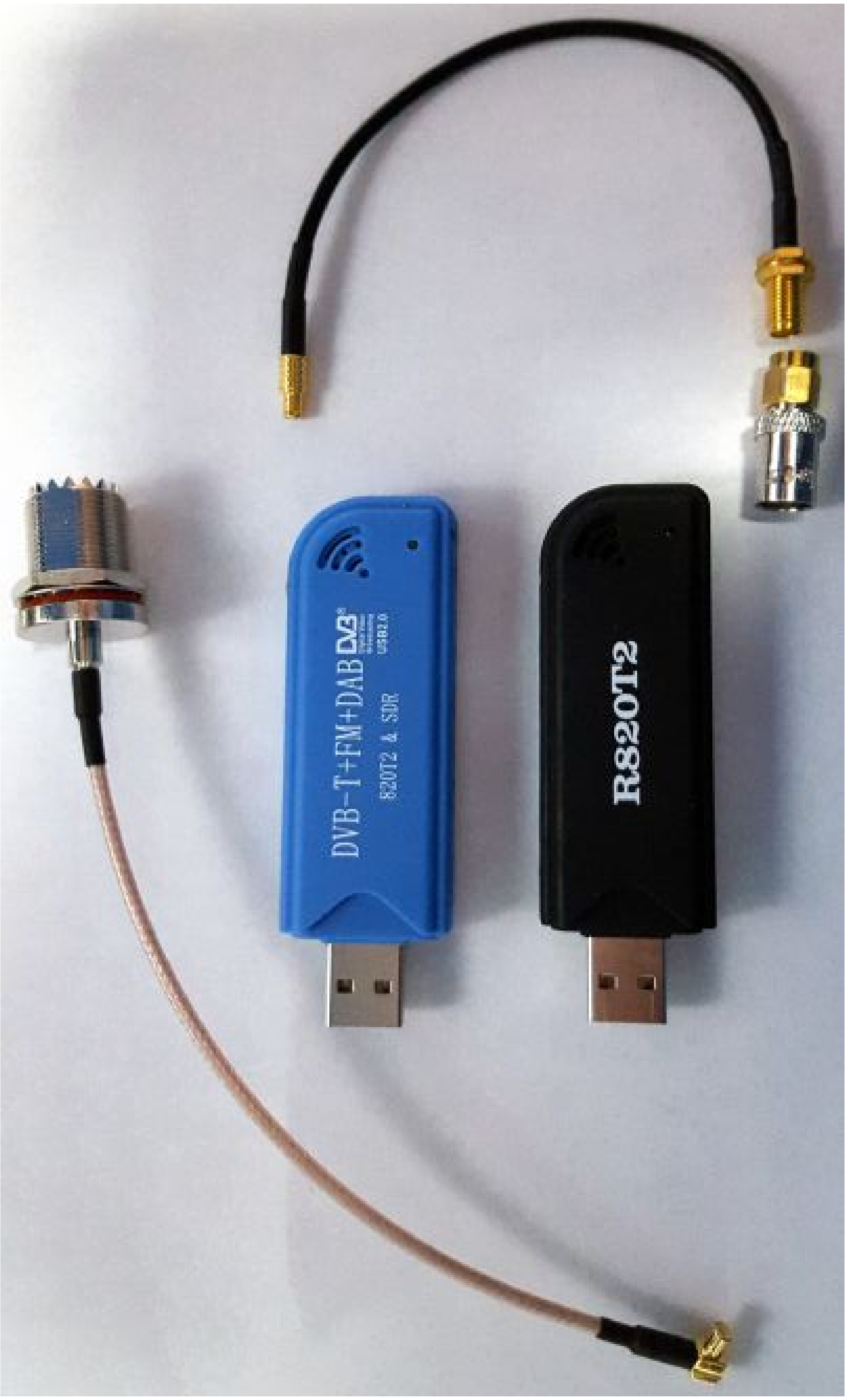

figure 1. RTL-SDR dongle

figure 2. V-Dipole antenna

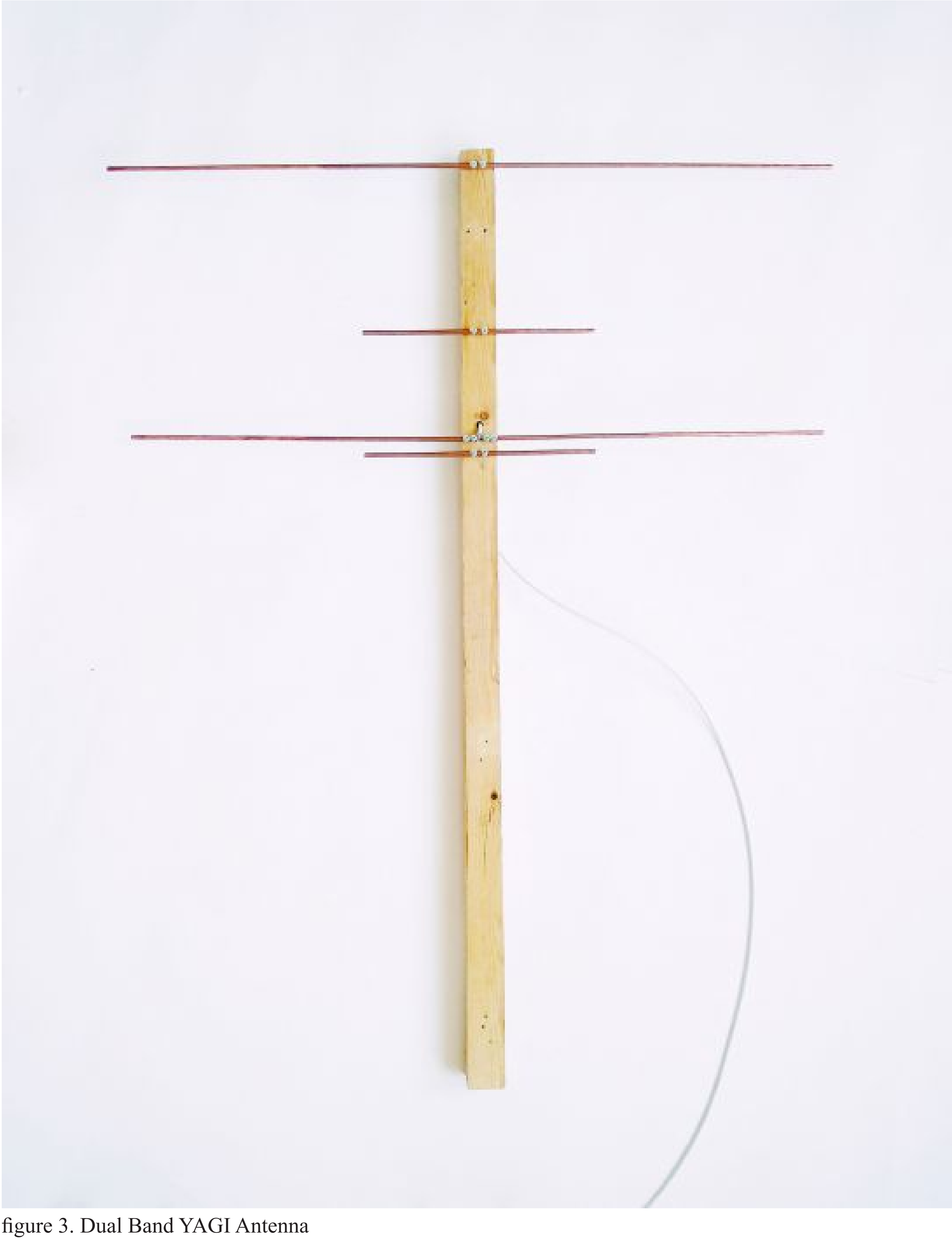

figure 3. Dual Band YAGI Antenna

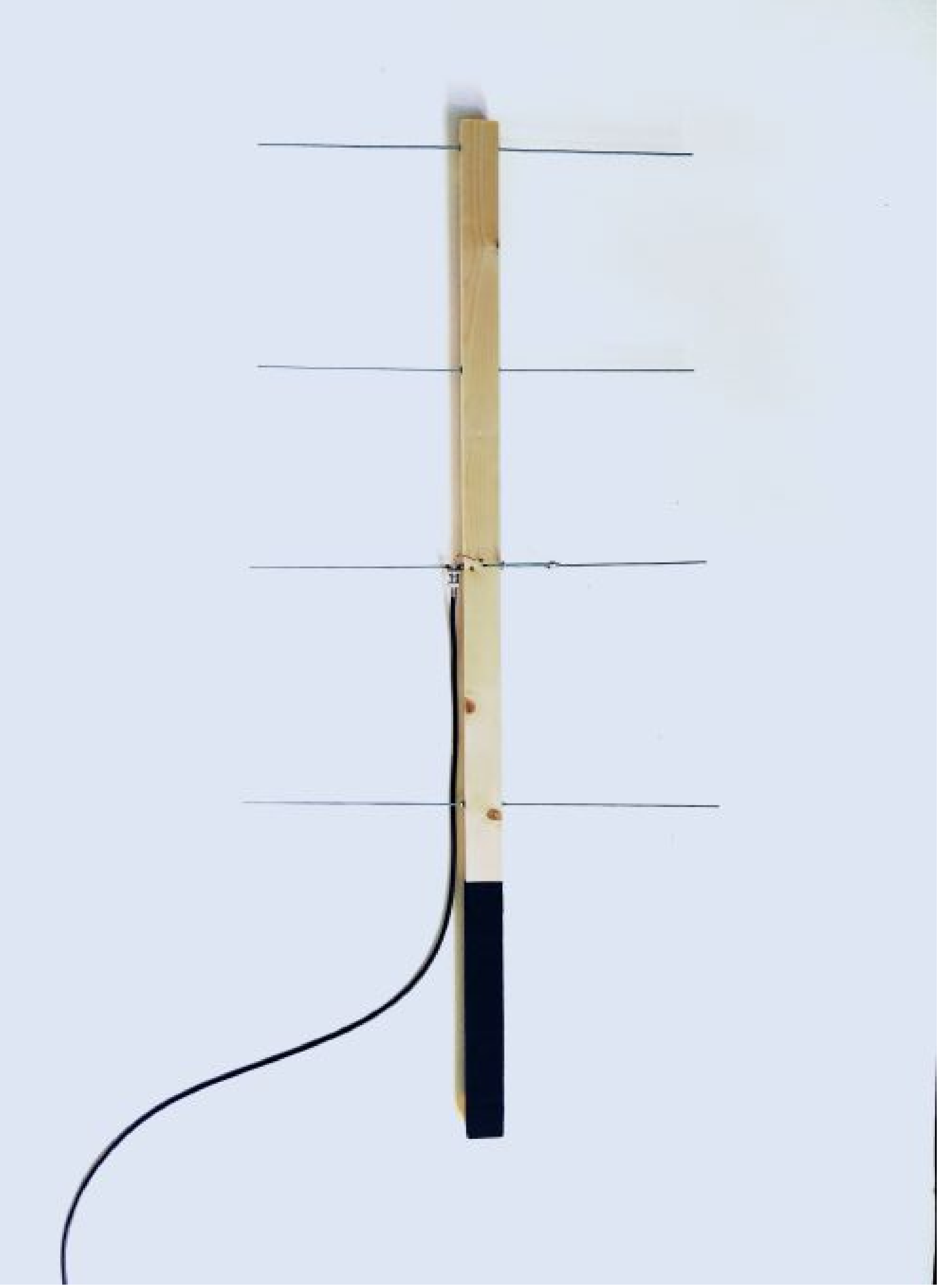

figure 4. YAGI UHF

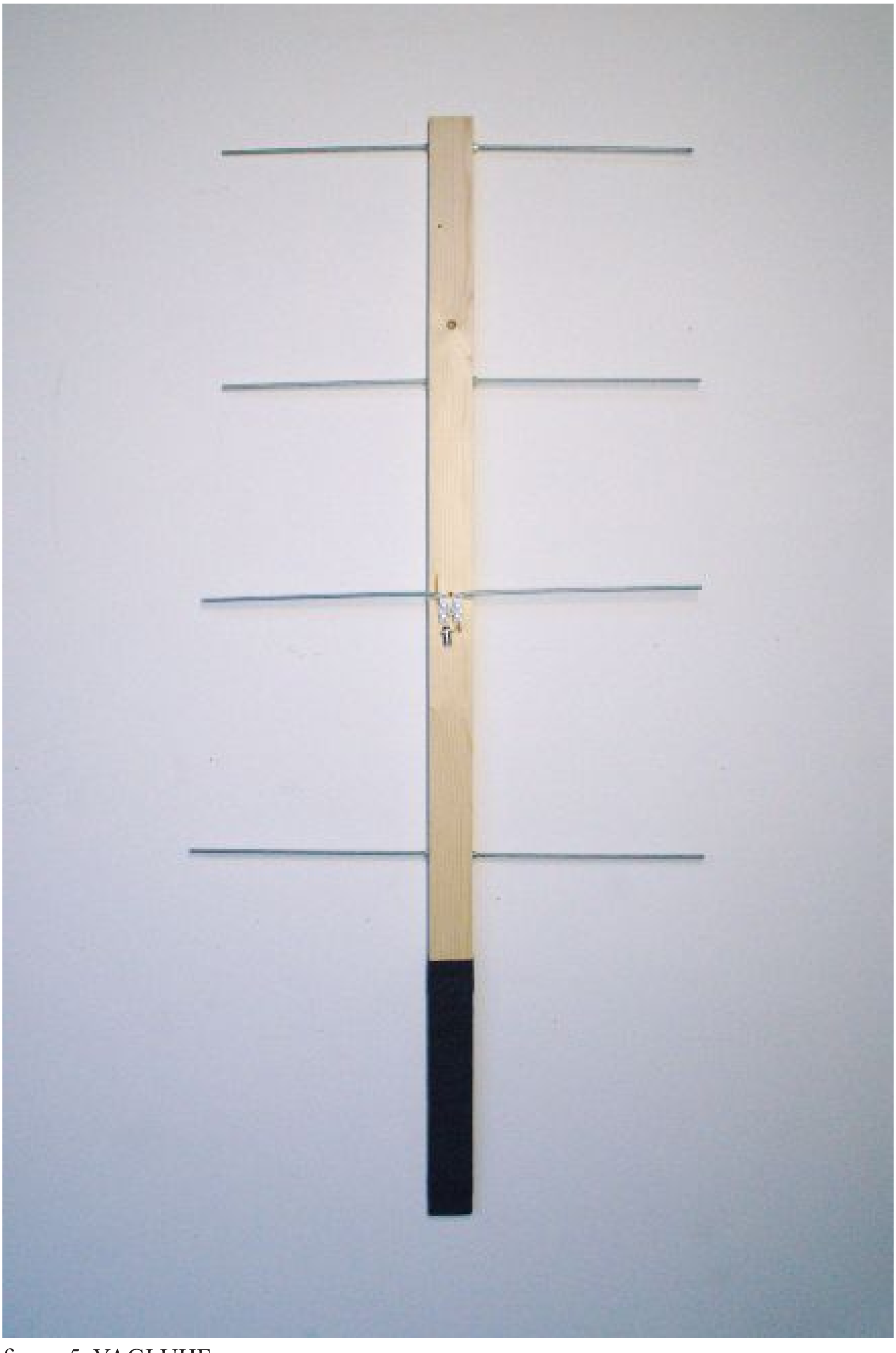

figure 5. YAGI UHF

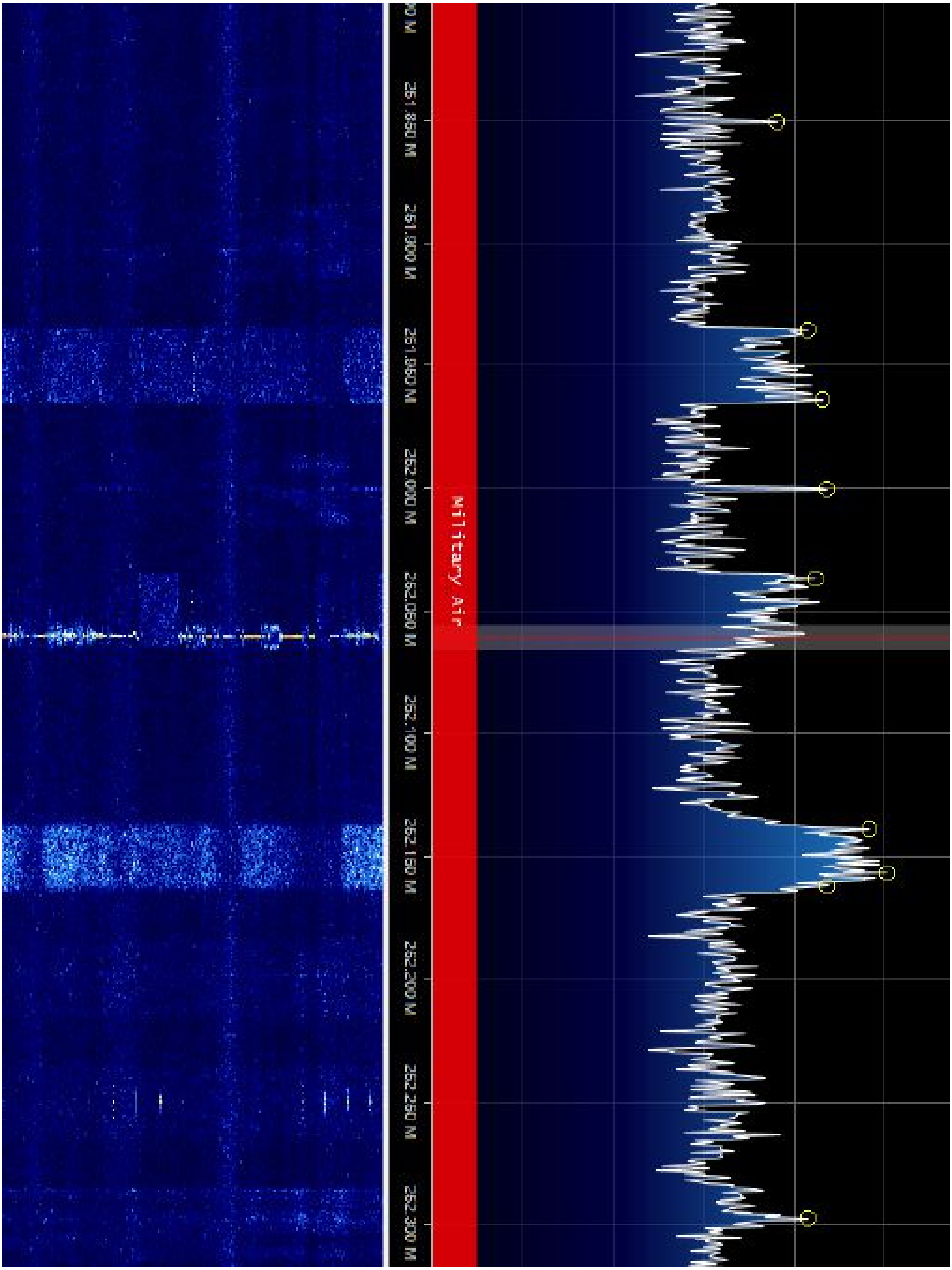

figure 6. SATCOM reception

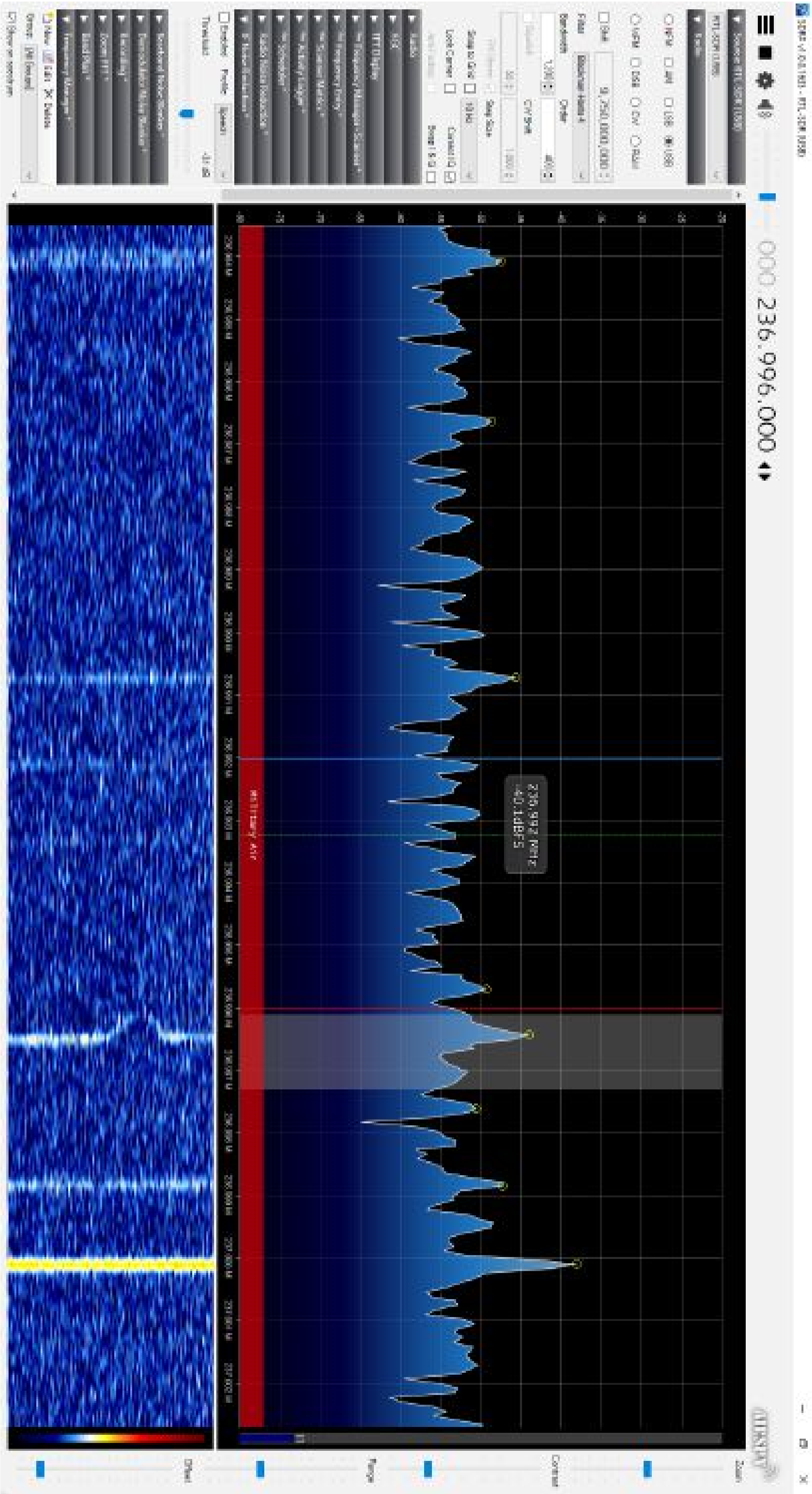

figure 7. LES-1 reception

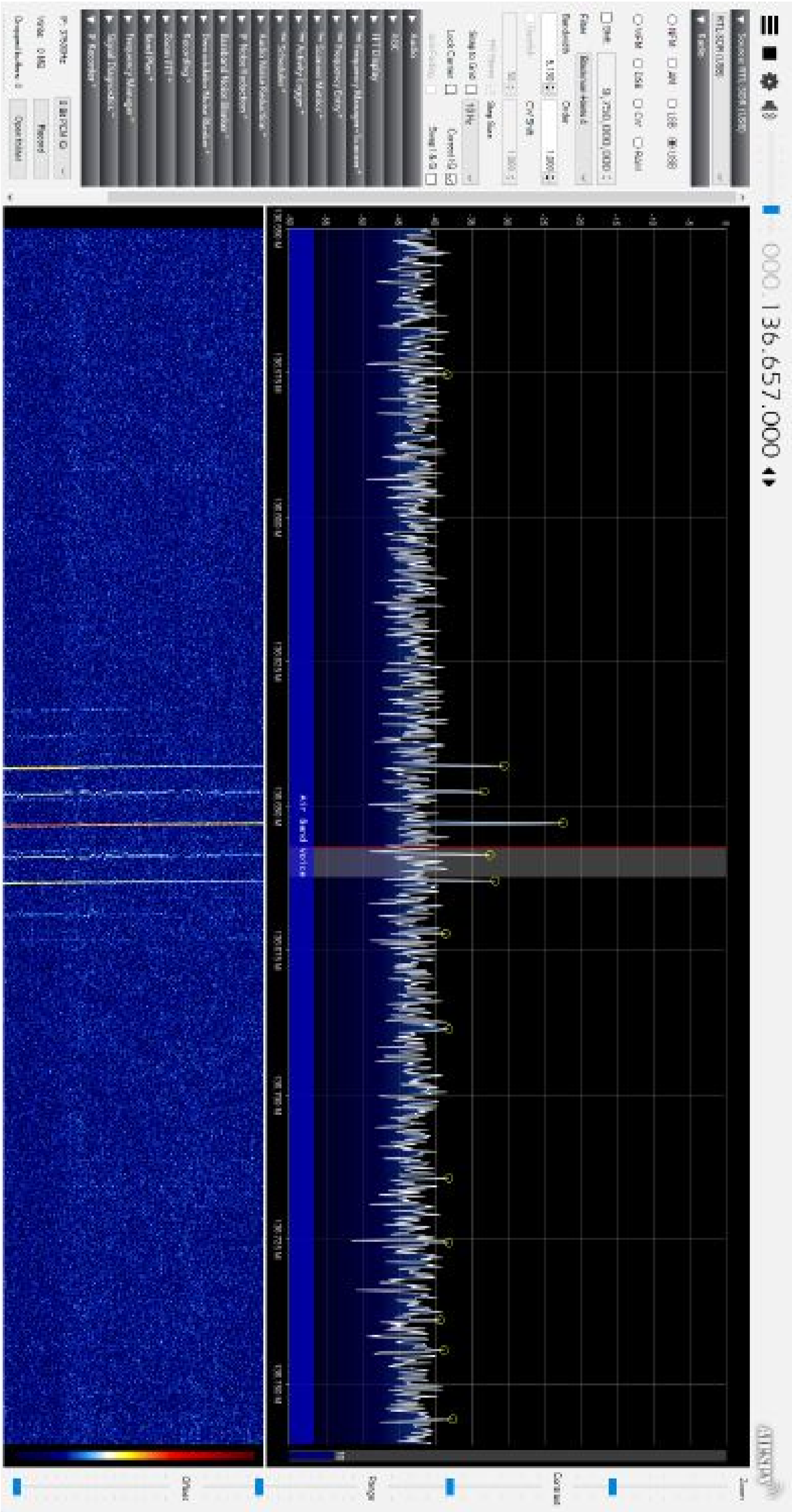

figure 8. reception Transit 5B-5

figure 9. full spectrum image

figure 10. Performance Varia

figure 11. Republic Kugelmugel

figure 12 Signal hunting toolkit

figure 13 Signal hunting toolkit

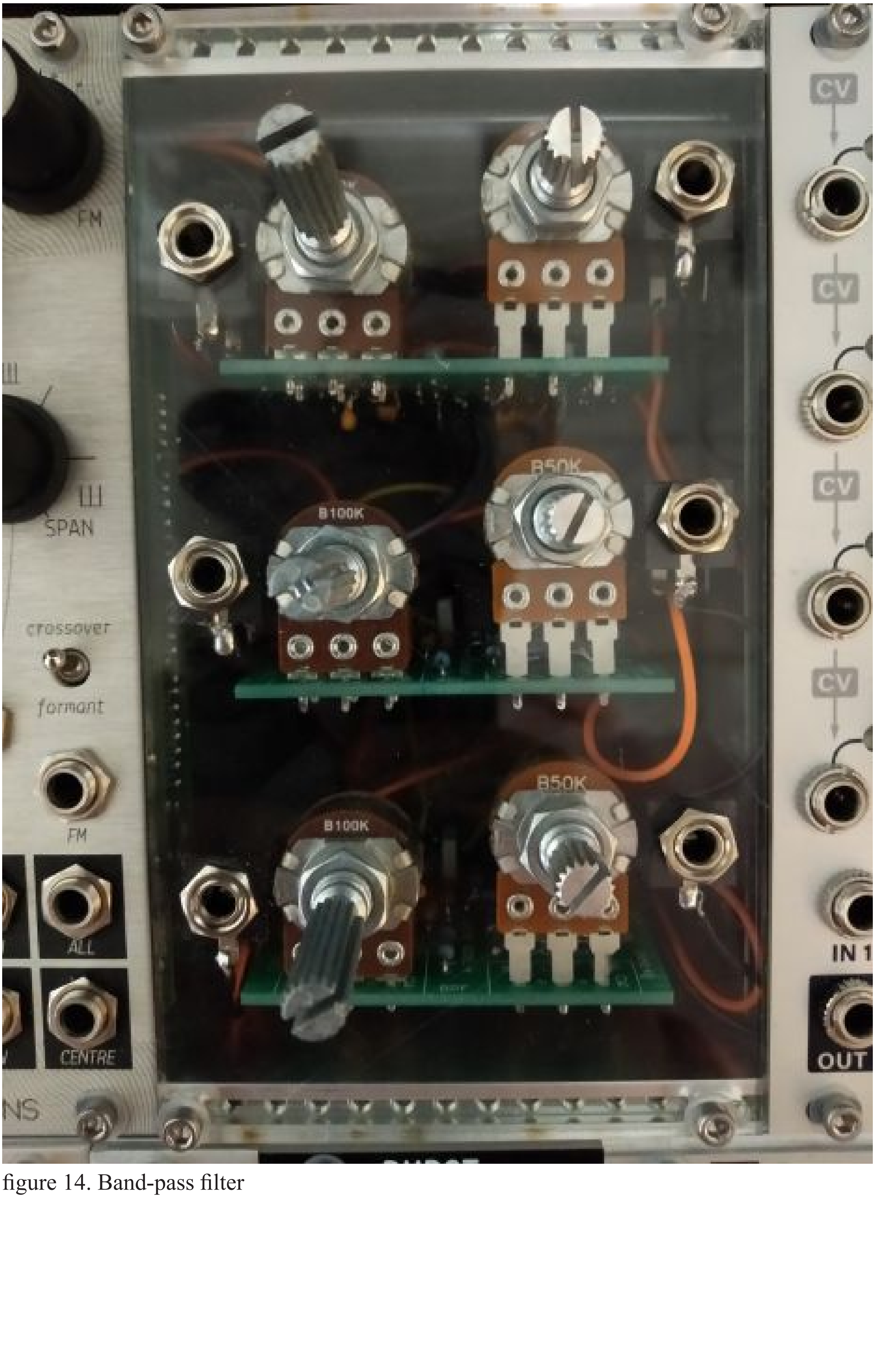

figure 14. Band-pass filter