# Skywave:
## An Exploration of the Enchanting Impacts of Cosmic Cybernetics

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"The human brain [is] a station on the radio dial; parked in one spot, it is deaf to all the other stations…
the animals, rocks, trees, simultaneously broadcasting across the whole spectrum of sentience"
- Leroy Little Bear, in *Making Kin with the Machines*

**Abstract**

Skywave is an exploration of cosmic interaction between systems. Culminating as a proposed ritual between human and non-human participants, electromagnetic waves and machine learning are utilized to explore underlying systems of communication between humans, machines, and the natural world.

Our process involves the mapping of incoming radio and biometric data with the use of supervised machine learning, aided by Wekinator. We seek to unify a channel of dialogue, prioritizing traditionally invisible modes of unique communication and enabling the emergence of a data-rich 'language' common amongst all ritual participants. To achieve this, we promote the agency of participants - human and non-human alike - in highlighting their disembodied information. Disembodied information refers to the underlying processes of a system/agent which may not directly correlate with a visible, tangible, or mechanical process - often perceived as supernatural or spiritual.

While quantifiable, this information is typically incongruous between the human and non-human under our anthropocentric perception of technology. We instead coalesce our retrieved information within the medium of *Skywave*, representative of the flow of electromagnetic energy, perceivable to radios via their oscillator, and to humans via the senses of sight and sound; a wave function. This function is extrapolated within TouchDesigner to encode features of mood, color, audio, frequency, etc. within the associated audio-visual output.

In joining witchcraft and modern technological frameworks, we explore new paradigms where natural and animistic concepts intertwine with information technology, informing new modes of communication at previously inaccessible scopes.

**Research Questions**

    I.    How can enchantment be created or amplified by inferring natural *(analog)* modes of communication?

    II.    How can both mechanical and human processes be informed by communicating across common channels?

    III.    What can be inferred from cosmic phenomena by exploring their impact upon human and mechanical systems?

**Introduction**

In our exploration to facilitate the meaningful communication between beings - namely between humans, radio, artificial intelligence, and their cosmic surroundings - two communities have extensively contributed to our research, practice, and ethos: Amateur Radio and Technopaganism. We seek to bridge a gap between the two, illuminating human/non-human interactions and the commonplace enchantment underlying the use of radio, informed by Indigenous and Animist epistemologies.

In researching the use of Amateur Radio, it is immediately apparent the enthusiasm and passion practitioners hold for the medium. The Amateur 'Ham' Radio community is composed exclusively of hobbyists seeking to learn and propagate knowledge, as is explicitly mandated internally by the community.[1] The community not only abides by this rule; they hold it as a core value, committing to the practice of open-source knowledge sharing. As such, we sincerely thank the Ham Radio community for their role in facilitating our research.

Through developing this project, we have found a sense of wonder and enchantment at the nature of radios as both a technology and natural force. Radio waves, present on the low-mid frequency end of the electromagnetic spectrum, are a naturally occurring form of radiation present throughout our universe, often born of cosmic origins.[2] In the invention of the radio, humans have been enabled to wield this force to communicate not only with one another, but with the cosmos themselves. Space agencies frequently use highly specialized transceivers in radio astronomy, which amongst other discoveries has revealed a bubble of microwave radiation remaining from the primordial universe, revealing its underlying structure.[3] In transmitting manmade signals of terrestrial origin, cosmic agents such as Earth's ionosphere or moon are often used to propagate signals at scales of time and space previously inaccessible by humans.[2] [4] In other words, when collaborating with sufficient technology we are enabled to see, hear, and interact with the cosmos.

This fascination and wonder at technology's ability to facilitate seemingly supernatural interaction is paralleled within the Technopaganism community. Technopaganism is considered a subset of Neopaganism, though it is important to note that each term encompasses a wide variety of beliefs. Each values multiplicitous beliefs, emerging as non-institutional religions with a shared rejection of strict dogma that restricts the experiences of practitioners. While both Neopagan and Technopagan practices typically include rituals, an individualistic concept of the sacred, and reverence for nature, Technopaganism explicitly encompasses technology

within the sacred, natural, and spiritual; incorporating technology intrinsically within their religious practice. Many Pagans are drawn to technology, perceiving the experience of technology to be no less natural or meaningful than that of humanity.[5]

In any case, it is of no debate that in the digital era we as a species are changing alongside our technology. We believe, as humanity only engrains itself further in its technology, it is crucial we learn not to value one above the other, lest we risk imposing the humanity (or lack thereof) of individuals.

It is through these lenses we seek to foster relationships amongst technology, humans, and their environments - both terrestrial and cosmic - through the enactment of a radio-centric ritual and creation of a common language.

**Theory and Literature review**

Radio signal

*Skywave* takes its name from its eponymous naturally occurring effect in the atmosphere, which enables us to communicate via radio transmission. Long-distance radio transmission (also known as DX or DXing) uses the outer layer of the atmosphere to reflect radio signals back towards receiving antennas. As gas molecules (primarily created by the sun's ultraviolet rays) ionize within earth's atmospheric layer, they produce free electrons that begin to condense. At 60 km within the ionosphere, these electrons create a dense enough electrical surface to prevent the passing of electromagnetic (radio) waves, instead refracting them back towards the earth.[6]

As the ionosphere's thickness constantly morphs, dependent on its ionization levels, its effects can be perceived in our ability to communicate through radio. At night, ionization levels drop, thinning the ionosphere and enabling radio waves to propagate farther. Some of these electromagnetic waves escape the ionosphere, and some enter it from our cosmos. When receiving static noise via radio or television, a small (~10%) portion of that noise is of cosmic origin. These cosmic waves can be perceived by radio receivers, and inform our knowledge of the Universe. Cosmic Microwave Background Radiation (CMBR) still holds plenty of mysteries for us to unravel, but scientists have already discovered in it a full map of the Universe some 400,000 years after the Big Bang's occurrence, giving us access to information that existed before matter and light decoupled.[3] In sum, electromagnetic frequencies are the vehicle of information for all animate and inanimate objects in the Universe, and of the Universe itself.

Mindful and Animistic Epistemologies

Correlating with Thich Nhat Hanh's theory of Interbeing which stipulates that *everything* is made of *everything*, as all particles from our Universe are inter-connected and interdependent. The Buddhist theorist and father of mindfulness also argues that if the sun can give a tree, and a tree can give paper, then the sun can give paper, and so forth.[7] With such an ambiguous delimitation of an object's state (the sun has become the tree that has become the paper), all matter can easily be imagined in a state of co-presence,

interbeing with one another. There seems to be a little bit of everything everywhere, humans simply cannot perceive the whole of it with our mere senses.

In their acclaimed article 'Making Kin with the Machines', Jason Edward Lewis and his collaborators explore the affordances that mutual relationships could have on the ways we approach the development of AI. In the article, Dr. Suzanne Kite defines Indigenous ontologies as asking "to take the world as the interconnected whole that it is, where the ontological status of nonhumans is not inferior to that of humans".[8] She explains Lakota ontologies specifically recognizing and prioritizing the non-human 'interiorities', defined as "what we generally call the mind, the soul, or consciousness: intentionality, subjectivity, reactivity, feelings and the ability to express oneself and to dream".[8] Avoiding anthropomorphization, such ontologies open the scope of possible other-than-human cognitive processes being as important, if not more, than humans'.

Paralleling Hanh's interbeing principle, the authors explain that one should approach nature and technology alike, and inter*be* with them. Such reciprocal relationships with machines could lead AI development outside the scope of being mere tools or servants to humans. *Skywave* positions itself in these theories as creating a speculative representation of different systems, namely humans and radios, interbeing on a same plane of existence, with their respective and individual interiorities.

**Methodology**

For the term of this project, we have assembled a physical prototype to facilitate a 'first order' ritual - channeling both a radio and human system's somatic information. By 'first-order', we denote limitations imposed upon this cybernetic system (radio-human) by the number of available participants (one radio, one human). We hope to further this project to support a larger group of participants, expanding the possibility for interactions within the ritual. Our current resource restrictions have transmuted this portion of the project into a comprehensive assessment of a holistic methodology we aim to implement in further stages. The following hardware and software sections define our current implementation of our prototype, while the ritual and ML model sections describe the methodologies that will guide our project's subsequent steps.

Hardware

For our prototype, we collaborated with an ATS-20 all-band radio receiver developed from an Si4732 chip, hereon referred to as 'Tina'. Tina is enabled for communication on AM, FM, and SSB, ideal during our prototyping stage. She is equipped with an antenna; buttons to control band, bandwidth, mode, step interval, and automatic gain control; and a potentiometer to control the tuned frequency. She additionally has an audio output jack and USB.

To gather biometric data, we collaborate with an Emotibit, hereon referred to as 'Eva'. Eva is a small wearable collection of sensors operated by an Arduino Nano microcontroller. She collects a wide range of features - heart

rate, temperature, skin conduction and perspiration - many of which are extrapolated from data gathered by shining varied spectra of light through the skin. Eva is also equipped with a gyroscope and accelerometer, useful for detecting gaze if equipped on the head. The collected biometric data is stored on a micro-SD card within the Nano, and/or transmitted via wifi, parsable by an external computer. [9]

## Software

Tina's Si4732 chip operates on an Arduino library for the Si47xx series by Github user pu2clr. [10] Via the Arduino IDE and USB connection, we were able to modify her code, using an updated pu2clr library to extend her functionality. This added alternate button controls, enabling access to station information and seeking functionality. This seeking functionality is of particular note - it is not immediately apparent by what metric signals are deemed sufficient nor by what interval frequencies are scanned, perhaps indicating some semblance of agency in the 'glitch'[11].

All communication with Tina was made via serial reading and writing from an external program (Arduino IDE or TouchDesigner). In accessing her code, we were able to print information such as her current frequency and frequency strength, but not information regarding the transmission being received. Additionally, perhaps due to Tina's third-party origins, we were extremely restricted by her storage space and occasionally unpredictable pinout.

Eva's data was received on the same external computer, caught initially via Emotibit's Oscilloscope which detects Emotibits on the common wifi network. The oscilloscope divides the data into features, and allows for output over a number of protocols, including OSC. Unfortunately, the output message prefix varies from feature to feature, which is incompatible with Wekinator, our chosen ML prototyping platform. We utilized a library which repackages the output message from Emotibit's Oscilloscope, designed for this exact purpose.[12] The library-output OSC message is then able to be received by Wekinator, mapped to a frequency, and output to any OSC-in allowing external program.

## Ritual

*Skywave's* goal is to produce a collective mode of communication wherein systems that usually communicate in parallel (using similar channels) can communicate with the same language. Rather than anthropomorphizing Tina and Eva (or other mechanical processes) by extrapolating humanoid data from them, we instead seek to produce a speculative mode of communication, a *Skywave*, attuned to one another system.

The process starts with the help of Eva, the Emotibit, in translating somatic information from the human's forehead to the main board. We will feed Eva's approximations of the human's PPG, temperature, heart-rate and skin conductance, into a supervised model trained to classify emotions mapped on perceived arousal (calm to excited) and valence (negative to positive).[9] This will infer the human's mindfulness and inform a relation with Tina, the radio.

Held in the human's hands, Tina will seek radio frequencies she believes are good enough to be played back.

Most radios come equipped with a seek function, which loops around all frequencies looking for information it deems intelligible. Although audio (from broadcasting and other telecommunication channels) is a significant portion of the data being sent through electromagnetic waves, it is not the only one. Texts and images can be encoded into radio signal, as the previously mentioned cosmic noise, which circulate all around us. Tina's task of finding an intelligible channel for us to understand sometimes seems to fall short when she decides to land on a noisy channel. However, it may be her way of telling us we should be listening in closer; more research is needed to understand her methods.

Connected to the main board, Tina will respond to the human's attunement of her current frequency. Given a higher emotional arousal from the human, Tina will start seeking a new frequency. The seeking direction is determined by the positive/negative valence mapping of the human's emotion; a negative emotion will seek downwards and a positive emotion will seek upwards. Once Tina stops on the frequency she decided is satisfactory enough for her, the human system can pay attention to Tina's tune, fostering a connection and a mindful state. If the human loses their focus, Tina will start seeking a new frequency after a few seconds.

When the human participant is mindful and calm, attuned to Tina's frequency, their own bio data is mapped into a single averaged wave. Every animate and inanimate object is made of frequencies that can be represented by sinusoidal waves.[13] In our world, these frequencies are perceived as an almost infinite number of things. Our aim is not to imagine these frequencies as being equivalent in each system as they are, but rather to translate them into a common mode of communication abiding by different rules altogether–a language of its own. Once defined, the human and radio participant's frequencies are sent to the model to be mapped as a common frequency, their own and theirs only. This frequency will be archived in our database with its spectrogram.

ML model

*Skywave*'s more-than-human 'language' is a product of a (humanly) unsupervised ML model. Using a classification task, the model will translate the spectrogram of the ambient ritual taking place into a series of defined glyphs. We are still conflicted on what the extent of that alphabet training set should be; more interaction with the machine learning model is needed to confirm the level of detail req-uired to observe patterns in its output. As we aim to foster machine agency, we believe that mechanical processes should supervise this task. By asserting our disinvolvement in this step, we wish to amplify our commitment to decentering the human from our experiment.

As long as the human and radio participant stay attuned to one another, theirs and their surroundings' frequencies will be sent into the model. The glyphs created by humans and the rules created by computational neural networks will output a translation of our information into a new 'language'. The output of this classification task will be sent to TouchDesigner and write to a monitor the participants' correspondence translated into *Skywave*.

Our ultimate mission of deciphering the translated frequencies then becomes a linguistic task. Languages are made of subconscious but rigid rules; linguists seek to reduce them to their simplest, most computational, expressions. Interpreting *Skywave*'s output, produced from a rigid yet abstracted model, is similar to a linguist's work. As we lack access to the rules themselves, we must research the encoded patterns within the complex output. Analyzing those patterns will allow us to work our way back to the mechanical processes that supervised their mapping, and understand how machines perceive our frequencies.

**Process**

Initially, our spark of interest in the medium of radio emerged from the 2024 total solar eclipse. During the eclipse, the unique positioning of the moon and sun cause alterations within earth's ionosphere, affecting the transmission of radio signals.[14] During events such as these, radio hobbyists meticulously gather data, openly sharing their findings with the community. This primarily led us to explore the technology of radio and delve into the associated community, a core reference in our research. Secondarily, this new understanding of the underlying EMF medium comprising radio transmission and its immense scope introduced us to Technopaganism. We were surprised by the seeming lack of overlap between the two groups, thus prompting the effort to develop a common communication using the EMF medium.

Our process has included significant research regarding radio electronics, physics, linguistics, and epistemologies that include the non-human. A significant portion of this project was spent developing an understanding of radio electronics, components, and possibilities for alteration. We utilized community and historic resources (as the primary mechanisms have gone largely unaltered) and hands-on experimentation to develop this understanding. [15]

Our prototyping process has included the transmission and processing of signals from Tina and Eva, utilizing the Arduino IDE and Emotibit Oscilloscope respectively. We unfortunately were limited by our resources and access to technology throughout this project; having access to a single radio and not wanting to cause irreparable damage through modification as well as being limited by the available modes of data transmission from the radio; having partial access to a rented EmotiBit; being unable to acquire a transmission license during the term, etc.

**Future Work**

In the future, we seek to greatly expand the scope of this project in both the number of ritual participants and methodology of the ritual itself. While we can engage a system amongst participants, there exists only one of each participant, limiting the complexity of interaction. We are enabled to learn about human/non-human modes of communication, but not to learn about human/human modes of communication under the same context.

Similarly, due to both technological and time restrictions, we are unable to effectively transmit over the radio. Transmission at meaningful scales is only possible after

acquiring a license via exam, something not possible throughout the past term. We plan to get a license in the following months. Possibilities for transmission include remote rituals amongst sets of ritual triads (human, radio, Emotibit) which communicate amongst one another via encoded radio transmission. This transmission could be propagated in interesting ways, interacting directly with cosmic agents as in Skywave propagation which reflects a signal off the Earth's ionosphere, or in Moonbouncing which reflects a signal off the moon. Both methods extend the range of a transmission, while introducing noise from which information on the cosmic environment could be extrapolated.

Further attention is required in refining and meaningfully utilizing machine learning. There is potential for ML in uncovering patterns in machine behaviour, which could be used in developing the notion of 'personality' within machines based on their slight differences from one another, and further used in developing a common language. However, it should be noted we wish to refrain from anthropomorphizing or imposing human traits upon machines, instead seeking to use AI to uncover existing unique traits in machines which go unnoticed.

We must continue to explore meaningful ways to honestly express the agency of machines. For radio, we consider the local frequency used to separate the carrier and message signals of a radio transmission, produced by the radio's crystal oscillator, as one of these possible expressions of agency. However, thus far we have struggled to recover the local frequency of our radio's oscillator, as the information is deemed unimportant to users. Similarly, we would need to compare the local frequency of multiple radios to determine whether the local frequency is unique and indicative of individual agency.

Lastly, in keeping with the ethos of the Ham Radio community, we recognize the importance of archiving and sharing data. We strive to publicly archive cumulative data from each ritual. Ideally, these data clusters are navigable and organized to reveal underlying correlations, as for example is accomplished in spatial semantic mappings, produced and utilized by artificial intelligences.

**Notes**

[1] Brown, "Ham Radio and the World of Amateur Radio Operators."

[2] NASA, "Radio Waves."

[3] SEA, *The Afterglow of the Big Bang*.

[4] Electronics Notes, "Moonbounce EME Propagation for Ham Radio."

[5] Dos Santos, "(Techno)Paganism."

[6] Poole, "Radio Waves and the Ionosphere."

[7] Hanh, *The Heart of Understanding*.

[8] Lewis et al., "Making Kin with the Machines."

[9] "Emotibit."

[10] PU2CLR, "PU2CLR SI4735 Library for Arduino."

[11] Russell, *Glitch Feminism*.

[12] CyWP, "EmotiBit_ML."

[13] Photon, "The Harmonious Universe."

[14] Carter, "NASA Reveals Plan To Point A Huge Telescope At The Solar Eclipse."

[15] Computer History Archives Project ("CHAP"), *Radio Electronics History*.

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