Open Research Institute Inner Circle Newsletter December 2024

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Open Research Institute is a non-profit dedicated to open source digital radio work. We do both technical and regulatory work. Our designs are intended for both space and terrestrial deployment. We're all volunteer. You can get involved by visiting https://openresearch.institute/getting-started

Membership is free. All work is published to the general public at no cost. Our work can be reviewed and designs downloaded at https://github.com/OpenResearchInstitute

We equally value ethical behavior and over-the-air demonstrations of innovative and relevant open source solutions. We offer remotely accessible lab benches for microwave band radio hardware and software development. We host meetups and events at least once a week. Members come from around the world.

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Regulatory Work at ORI

Making Open Source Easier for Everyone

Past regulatory work at ORI can be found at https://github.com/OpenResearchInstitute/documents/tree/master/Regulatory

219 MHz Project

by Mike McGinty

FCC LicDB

Federal Communications Commission License DB (FCC LicDB) is a set of tools for exploring the FCC license database dumps. The tools are at https://github.com/tarxvftech/fcc_licdb

These database dumps are at the link below. https://www.fcc.gov/wireless/data

What you see in FCC LicDB is a way to download and then import most of the weekly database dumps to an sqlite database. Expect a couple gigabytes for uls.db, depending on how many services you import.

After that, the purpose of this repository gets more esoteric because it's less about exploring and more about answering. (Answering what?)

There's a problem with the 219-220 MHz band. 47 CFR part 80 defines this band (among others) as for Automated Maritime Telecommunications Systems (AMTS), but that idea completely failed and so now there are no AMTS stations, just companies licensed for AMTS, usually through leases, that use the spectrum for other purposes.

The restrictions on Amateur secondary use of the band defined in part 97 were designed for a world where AMTS stations were on the coast. This, along with other circumstance, define the problem that exists today - it is nearly impossible to operate an Amateur radio on the band despite hams deliberately being given the spectrum.

See https://github.com/tarxvftech/47CFR for more details on this situation. I started this LicDB repo to figure out where these AMTS licensees operate, and what they are using it for. The ULS database interfaces available to the public are not sufficient for answering questions like this (details in W5NYV's first talk "The Haunted Band").

But where a generic system may struggle, a more targeted approach can solve.

What you see here is a functionality-first view of the FCC licensing system mapping as much of the AMTS stations licensed or operating in the 219-220MHz band as can be found in the database.

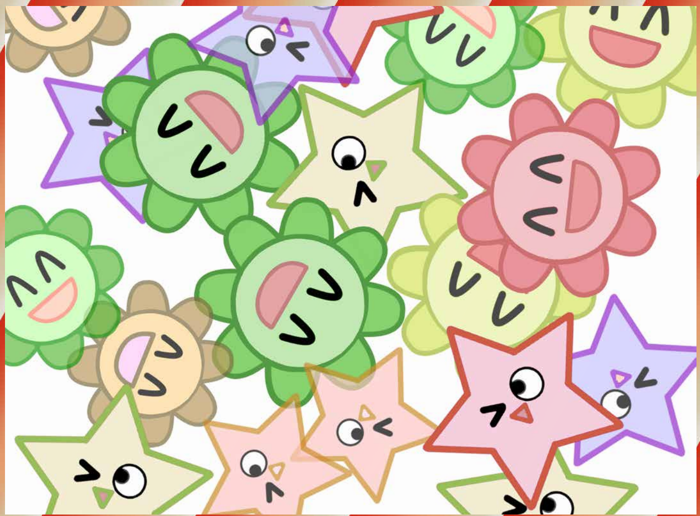
It's not perfect - working on data from other people and systems that you have no control over never is - but it's much better than all existing alternatives.

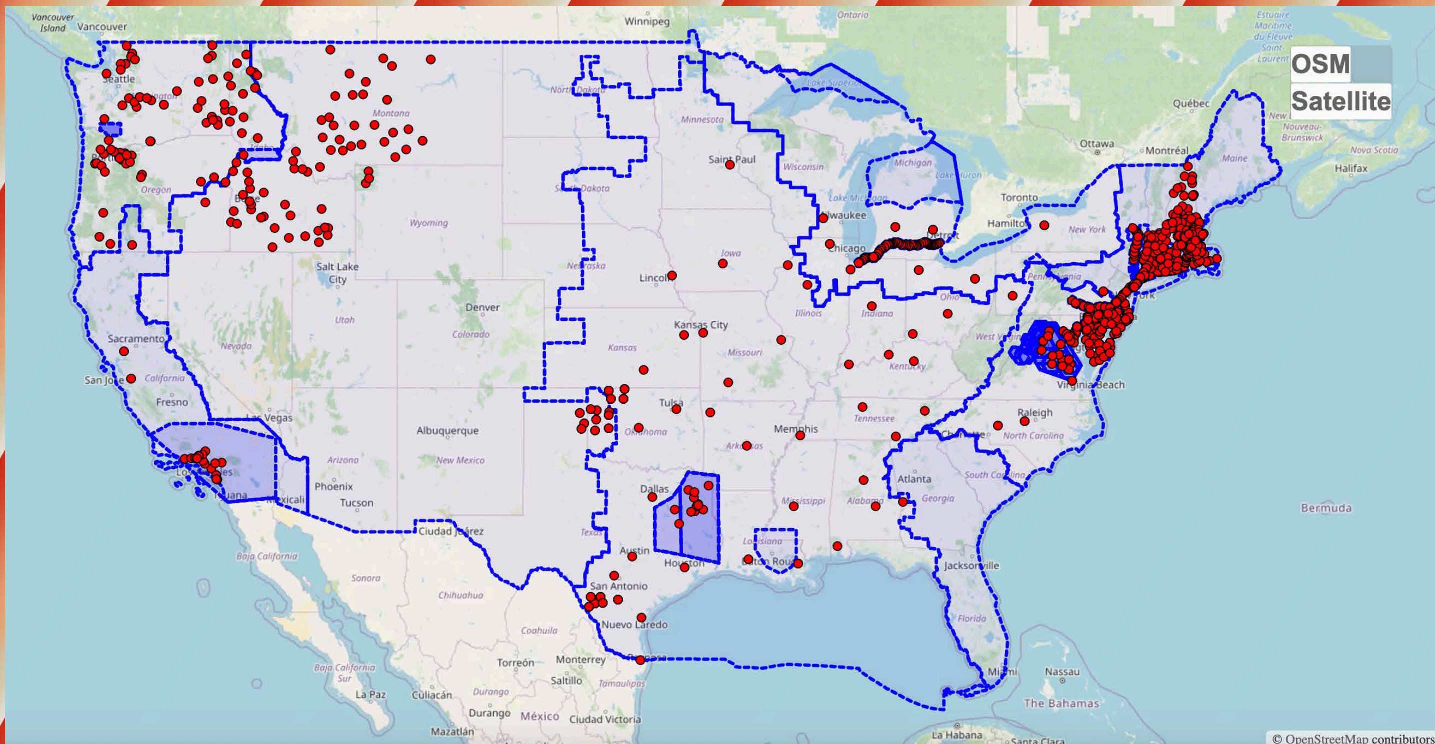
Other Projects

It's expected this would be useful for redoing W5NYV's exploration into the demographics of Amateur Radio operators in the US: https://github.com/Abraxas3d/Demographics

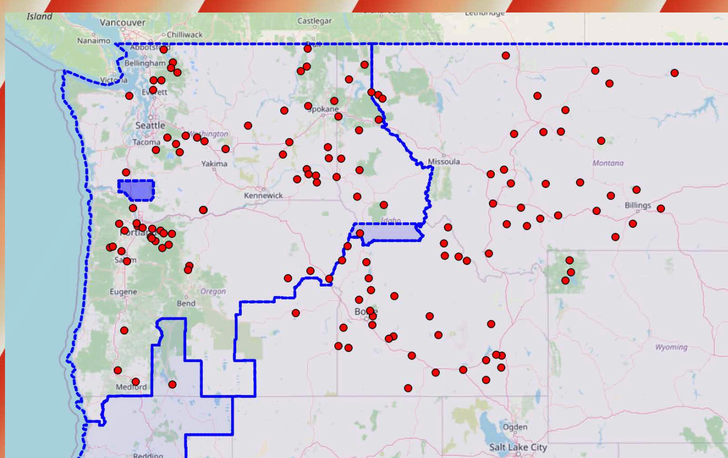
Similarly, it might be very interesting to plot ALL the LO, PC, and other entries, and then merge in the other data that isn't in the FCC database, like ham radio repeaters, to try to make the radio services in the ether around you that much more legible.

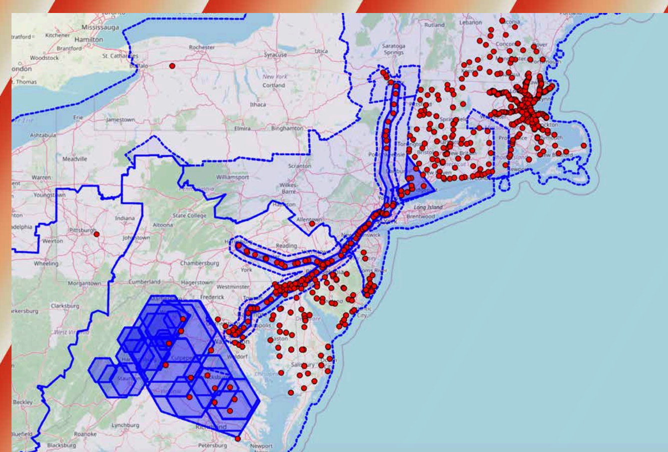
Some entries are not easy to import into the database, or have data errors that make them difficult to plot on the map. Those entities are not presently accounted for.

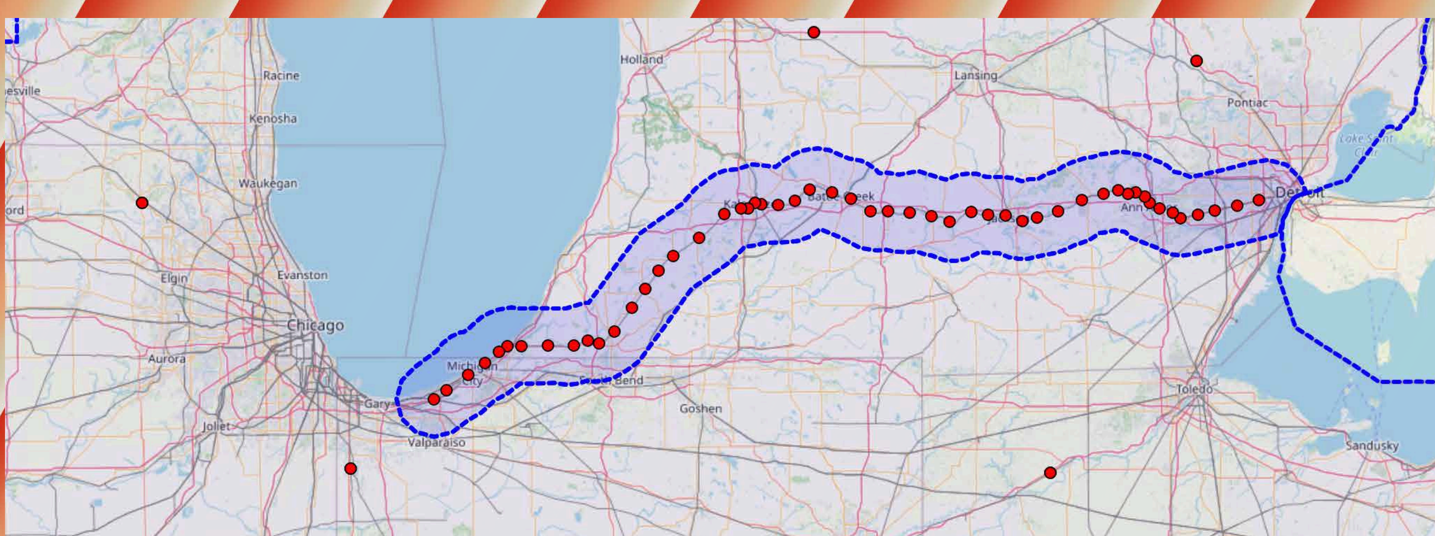




Above, AMTS stations in the United States. Below, a few detail images from the map, which can be found at https://amts.rf.band (heavy data, be patient for first load).







Space Frequency Block Coding Design for the Neptune Communications Project

Described is the design and implementation of SFBC for an amateur radio application called Neptune.

Introduction

There are many different ways to improve the resiliency of transmitted signals. For example, simply repeating the data we send some number of times is a simple and effective way to increase the probability that a signal will be received. We use repetition when we repeat a call sign or exchange in an amateur radio contest. If one out of three repetitions of the call sign refractions of the original signal. Multiple signals travel paths that differ in length. Because some of the reflected or refracted signals are taking a longer path to get to the receive antenna, the signals are time-shifted copies of each other. Different echoes traveling at different time delays can end up, worst case, cancelling each other out entirely. There could also be changes to the frequency and amplitude of the signal along some of these paths. This means we may get a very damaged received signal.

An article from ORI called "Space Frequency Block Coding Design for the Neptune Communications Project" will be in the January-February 2025 issue of QEX Magazine, from ARRL. Thank you to ARRL for publishing open source work from ORI.

Article Summary

The article discusses the design and implementation of Space Frequency Block Coding (SFBC) in the Neptune Communications Project, a digital radio initiative operating at 5 GHz for amateur radio applications.

Key Concepts and Objectives:
SFBC is a technique used in digital communications to improve signal resiliency by leveraging spatial, frequency, and coding diversity. It is commonly implemented in systems using Orthogonal Frequency Division Multiplexing (OFDM), utilizing multiple antennas for diversity. The mathematics are explained step-by-step with diagrams and equations. Noise calculations worked out in an Appendix.

Amateur Radio Application:
The Neptune project focuses on transmitting robust digital signals in noisy environments, essential for drone and aerospace communications. SFBC increases the likelihood of data recovery by mitigating multi-path interference and improving signal-to-noise ratio (SNR). An open source OFDM modem is needed in amateur radio.

Technical Details

Implementation:
SFBC transforms transmitted signal samples mathematically before sending them via two transmit antennas. Multi-path and spatial diversity enhance signal integrity against environmental reflections and interference.

Operation:
Signals are transmitted using OFDM, where subcarriers provide frequency diversity. The encoding does not increase throughput on its own but makes it easier to achieve maximum throughput performance.

Coding techniques like the Alamouti scheme are explained, with diagrams, for creating and decoding signals.

Trade-offs:
SFBC reduces SNR by 3 dB compared to optimal techniques like Maximum Ratio Combining but

avoids the need for channel state knowledge at the transmitter.

Practical Implementation:
SFBC was modeled and tested in MATLAB/Simulink, with plans for FPGA and ASIC implementations.

Future work includes:
Expanding to Space Time Block Coding (STBC)and live demonstrations of SFBC/STBC performance differences. Open-source release of HDL source code for hardware implementations.

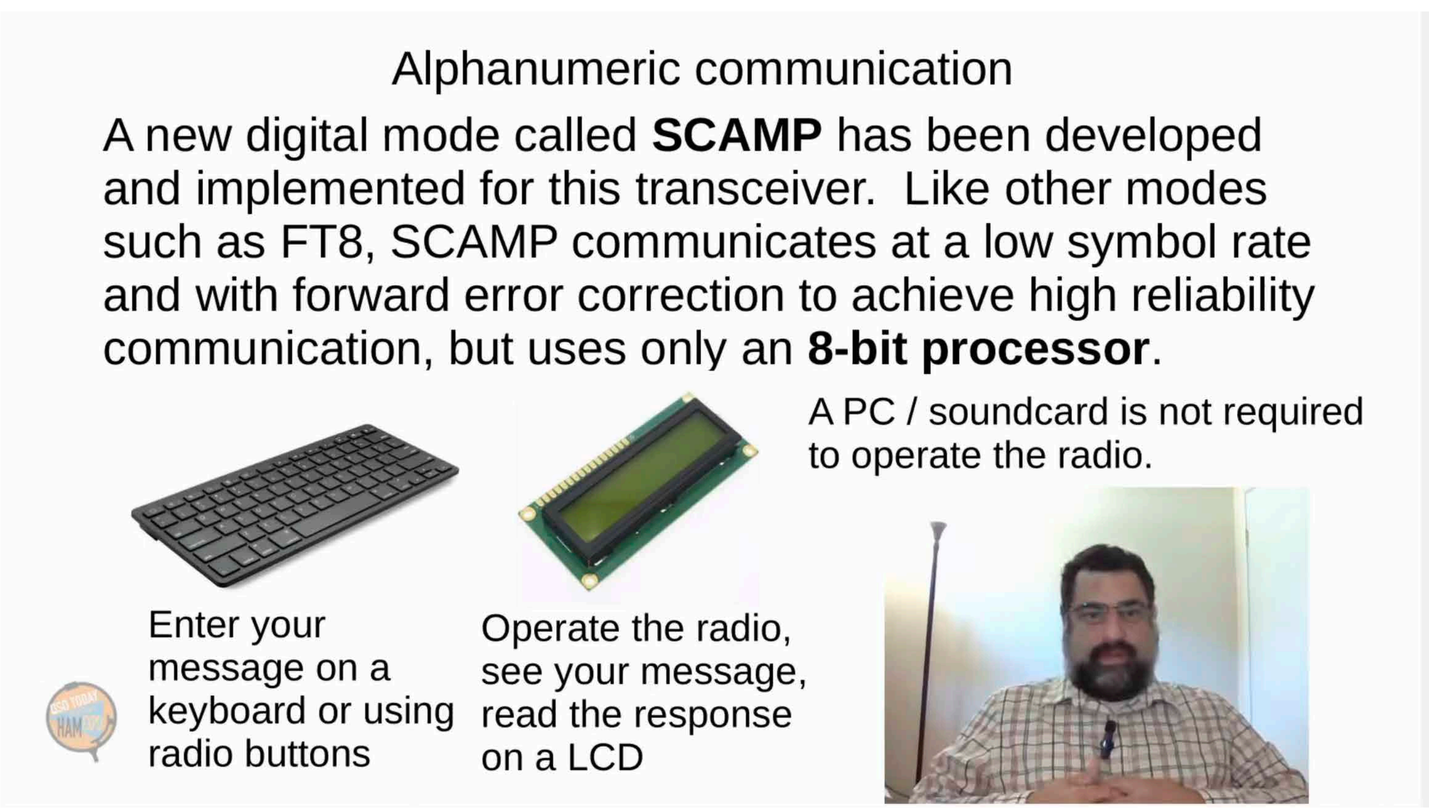
Call to Action:
The Neptune project is a volunteer-driven, open-source initiative under the Open Research Institute (ORI). Community participation is encouraged, providing educational and developmental opportunities in digital communication technologies.

SCAMP now in FLDigi

SCAMP mode is now included in the Op Modes of Fldigi as of version 4.2.06.07

Watch Dr. Marks explain the RFBitBanger project and the SCAMP protocol in this video at https://www.youtube.com/watch?v=Fbgs_4QsKnE

Get an RFBitBanger kit today at https://www.ebay.com/itm/364783754396



A Tale of Troubleshooting

Problem Solving our Minimum Shift Keying Implementation in the Lab

Minimum shift keying (MSK) is the modulation used by Opulent Voice, our open source uplink protocol for our space and terrestrial transceiver. Unlike some other modulations, there aren't a lot of documented and working examples of MSK, despite the many advantages of using this modulation for space and terrestrial channels. One of our educational goals at ORI is to provide exactly that, a documented and working example of MSK, that also delivers useful functionality to the amateur radio satellite service.

In the process of writing down a description of what happens mathematically, so that software defined radios like the PLUTO SDR can transmit and receive our Opulent Voice protocol, there's been quite a few troubleshooting sessions. One session solved a problem where the main lobe bandwidth was too large. Another session solved a problem where the processor side code didn't properly configure the radio chip. Another session switched to the correct version of LibIIO, or Library of Industrial Input and Ouput routines. The wrong library meant that the radio was "sort of" working, but not completely.

Troubleshooting and debugging systems is where most volunteer engineering time is spent. This is no different from professional development, where blank-paper time spent writing down routines may be a small fraction of the total development time of a project.

It can take multiple attempts to solve a problem. When this happens, it's important to back up completely and recheck basic assumptions. Looking at the images at right, one can see the desired MSK spectrum at the top. On the bottom is an example of an undesirable spectrum. The main lobe is bifurcated and the sidelobes have extra power. If you look at the graph, you can see that the sidelobes are higher in the "bad" example than they are in the "good" example. These are all clues, and there are several ways to go about attempting to solve the problem. The bad or "split" spectrum seemed to show up at random times, but it would go away when new PI controller gain pairs were written to the radio.

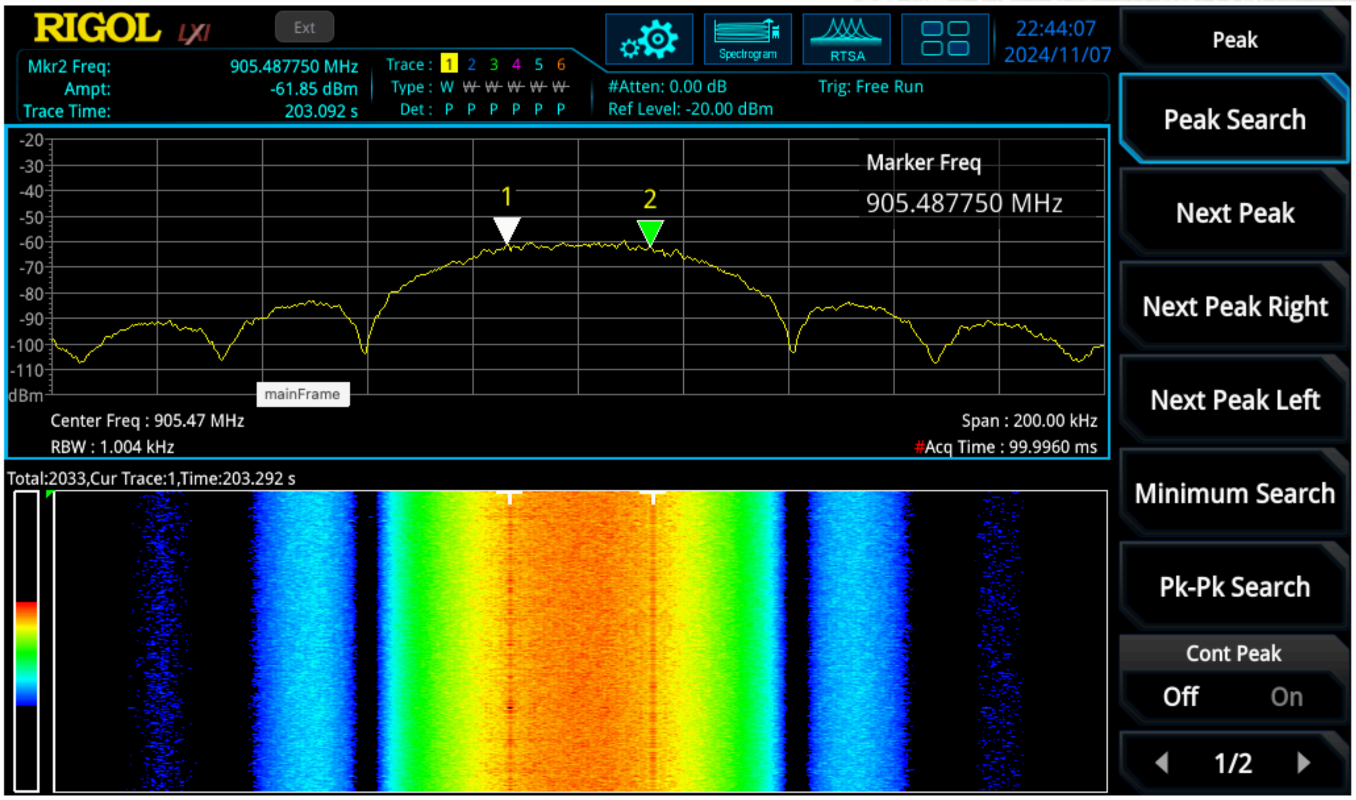
Why were we writing new proportional and integral gains to the radio? We were trying to tune our PI Filter, which is in the Costas Loop, which is in charge of tracking the frequency and phase of our signal so we can demodulate and decode successfully. We wrote code to search through proportional and integral gain pairs, testing their performance both in digital loopback and in loopback over the air.

After reviewing the code, asking for help, getting a variety of good advice, and trying to duplicate the problem in MATLAB, <u>the problem unexpectedly went away when the processor side code was updated to remove extra writes to MSK block configuration registers.</u>

The lessons learned?

* Clean code that matches the design of the hardware may prevent unexpected behavior. **Don't be sloppy with your test code!**

* Keep up to date on changes in register accesses and behavior. There was a change from setting and clearing a bit in a register to the bit being toggled. This was a change from level triggered to edge triggered. **Do your best to match what's in the hardware!**


RIGOL LXI
Ext
Mkr2 Freq: 905.487750 MHz
Ampt: -61.85 dBm
Trace Time: 203.092 s
Trace : 1 2 3 4 5 6
Type : W W W W W W
Det : P P P P P P
#Atten: 0.00 dB
Ref Level: -20.00 dBm
Trig: Free Run
Spectrogram
RTSA
22:44:07
2024/11/07
Peak
Peak Search
Next Peak
Next Peak Right
Next Peak Left
Minimum Search
Pk-Pk Search
Cont Peak
Off On
1/2
Marker Freq
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mainFrame
Center Freq : 905.47 MHz
RBW : 1.004 kHz
Span : 200.00 kHz
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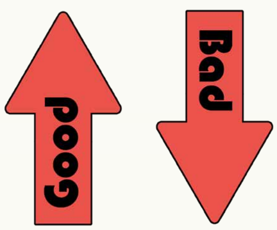
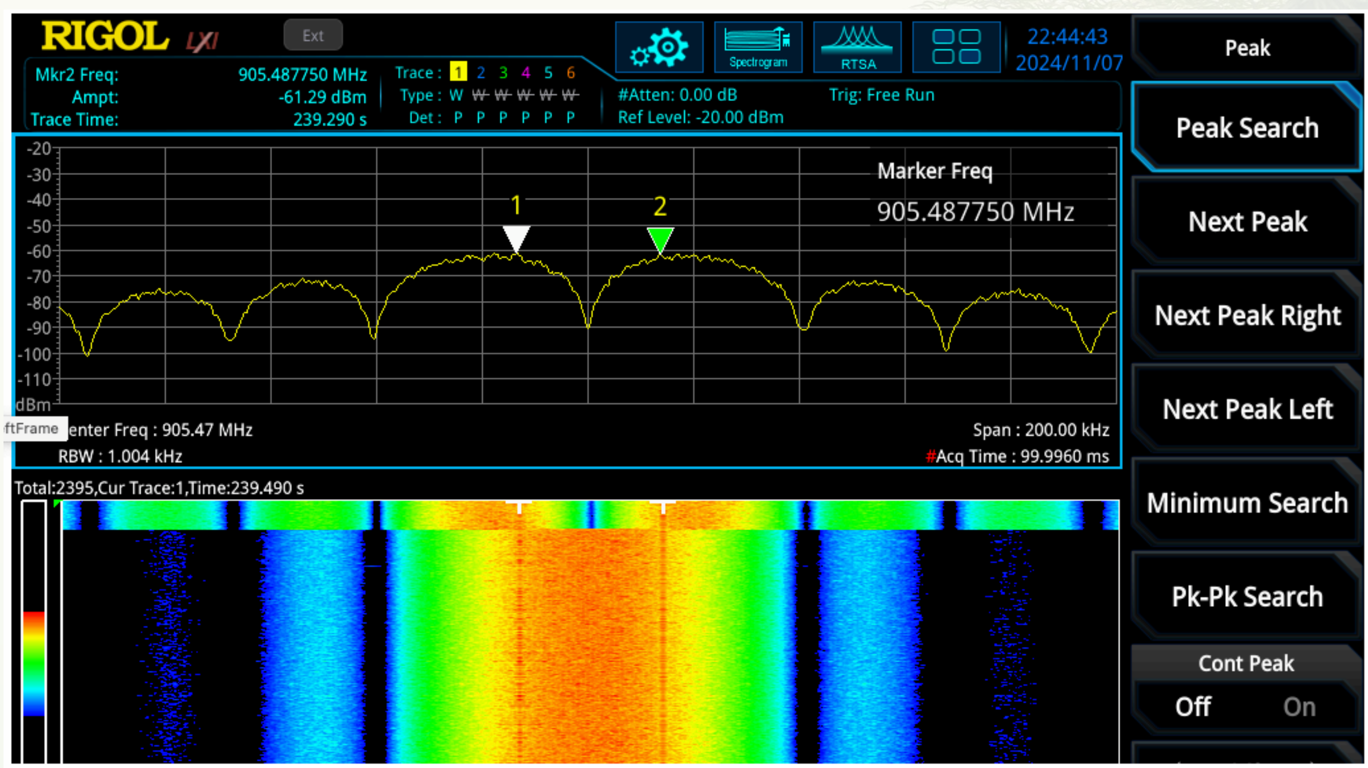

Good
Bad


RIGOL LXI
Ext
Mkr2 Freq: 905.487750 MHz
Ampt: -61.29 dBm
Trace Time: 239.290 s
Trace : 1 2 3 4 5 6
Type : W W W W W W
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#Atten: 0.00 dB
Ref Level: -20.00 dBm
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22:44:43
2024/11/07
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Minimum Search
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Cont Peak
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905.487750 MHz
Center Freq : 905.47 MHz
RBW : 1.004 kHz
Span : 200.00 kHz
#Acq Time : 99.9960 ms
Total:2395,Cur Trace:1,Time:239.490 s

Opulent Voice Communications in Space (WX9XRJ) and Exploring the Upper Limits of the Biosphere

Nadja Aldarondo, Adrián Duchesne, Ainara Berrios, Ana Rivera,
Rodrigo González, Paula N. Román, Jorge Coppin-Massanet, Natalia de Jesús, RockSat Team, and Oscar Resto

Abstract

The RockSat 2024 flight will mark the inaugural space application of the Opulent Voice Protocol, an open-source, high-bitrate voice and data protocol, integrated into our telemetry system. Despite our knowledge of Earth as a habitable planet, the full scope of its habitable environments and the extent of the Earth's biosphere, particularly in the upper atmosphere, remain subjects of ongoing debate and exploration. While missions like Tanpopo aboard the ISS strive to answer these questions, their orbiting altitude of 400km leaves vast regions of the atmosphere unexplored and unanalyzed. Conventional exploration balloons, limited to an altitude of 40km, further underscore this gap in our understanding. To address this, a team at the University of Puerto Rico is leveraging the RockSat-X program to launch astrobiological biosignature detection probes on sounding rockets that reach altitudes of 160km. This initiative aims to enhance our understanding of life's extent on our planet and seek evidence supporting the Panspermia Hypothesis [1] for the origins of life on Earth. This year's BioSPHERE Nano: Biological Sounding Probe for Habitable Environments Remote Experiments V.2.1 Nano mission incorporated a range of astrobiology and upper atmosphere habitability characterization experiments. These primarily utilized environmental sensors, such as those for humidity, temperature, and pressure, to provide a more detailed profile of the upper atmosphere.

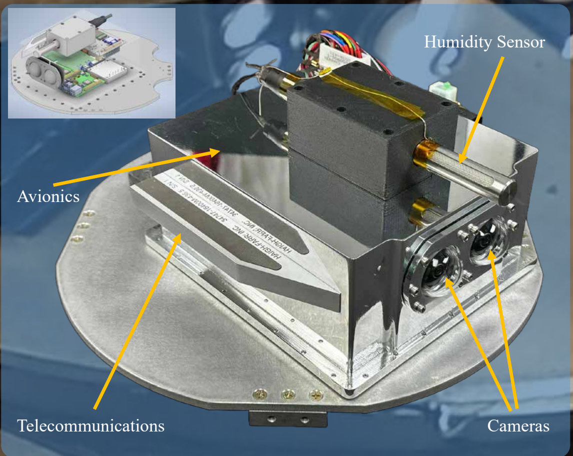
Introduction

In this groundbreaking experiment, the University of Puerto Rico team is poised to integrate a telecommunications subsystem, utilizing the Opulent Voice open-source protocol from Open Research Institute with an experimental space license WX9XRJ.

This innovative subsystem is specifically engineered for the transmission and reception of digital audio via the UHF band. Moreover, the project is dedicated to the creation of an exhaustive humidity profile of our atmosphere. This profile will be meticulously compiled using a blend of state-of-the-art technology and readily available sensors.

These instrumental tools will furnish the necessary environmental context for the detection of potential biosignatures. In tandem with these scientific pursuits, the team is also planning to record Virtual Reality (VR) footage of the flight. This immersive footage will serve as a dynamic educational resource, designed to stimulate interest and engagement in STEM educational fields.

Payload Design



The RockSat-X program establishes a benchmark for student payloads, designed to be launched on the Terrier-Improved Malemute sounding rocket. This rocket is set to ascend to an altitude of 160 km that is above the Karman Line, reaching into the Thermosphere layer of space, with the launch taking place from NASA's Wallops Flight Facilities. The program's guidelines necessitate that payloads fit within a cylindrical volume of 12" in diameter and 10.75" in height, with a nominal weight of 30 lbs. The rocket's ground support equipment supplies the payloads with 28V, boasting a maximum capacity of 1 Ah. The student payload is composed of five sub-systems: telecommunications, environmental sensors, cameras, power, and avionics. The telecommunications sub-system, utilizing the Opulent Voice Protocol, comprises a Raspberry Pi 4 computer, an ADALM-PLUTO transceiver, a Pre-Amp, Amplifier, and an Antenna. The environmental sensors include a cutting-edge humidity sensor, pressure sensor, and thermocouples. The video validation system features two PiCAM 360 stereo cameras, designed to record 360-degree footage of the flight. The power system incorporates two DC-DC 100 watts power converters, one for 5V and the other for 15V. The avionics system consists of three flight computers: a primary Raspberry Pi 4 for avionics and sensor data collection and downlink telemetry, a secondary Raspberry Pi 4 for the Opulent Voice Protocol, and an NVIDIA Jetson Nano to operate the cameras.

Expected Results

By comprehending the characteristics of our atmosphere by exploring altitudes of 0-170km, as a function of time and altitude, scientists can draw crucial comparisons and correlations. This enhances our understanding of water detection and its prevalence in other celestial bodies. Moreover, studying parameters like absolute humidity, which represents the actual amount of water vapor in the air, offers insights into the Earth's water cycle, particle movement, and the intricate processes that govern our atmosphere. Through the exploration of the upper atmosphere and the understanding of its properties, we acquire invaluable knowledge that contributes to the broader mystery of life and the role of water in the universe. Building on the findings from the data collected during the RockSat C 2022 mission, we aim to enhance the detectivity range to what we term 'mid-range humidity', encompassing a sensor measurement range of less than 1g/m³ to 0.1 ng/m³. The mission observed a change in humidity throughout the flight, validating the concept of detecting varying humidity concentrations at different altitudes.

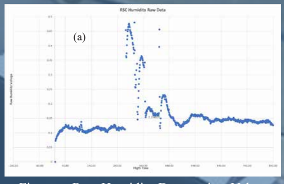


Figure a: Raw Humidity Data against Voltage

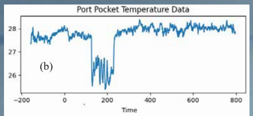


Figure b: Port Pocket Temperature Graphs against Time

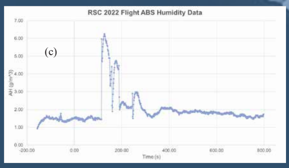


Figure c: Absolute Humidity against Time

After making a scientific trace study of available instruments, we developed 4 ranges of detectivity with the following instruments: Model AHT-200 Sensor, Shaw Model AcuDew, Unknown Available Sensors and a Mass Spectrometer. Newer sensors, like the Tunable Diode Laser Humidity sensor (Axetris) whose purpose is to detect humidity in all its states (molecular, liquid, or ice) on a later mission will be to discern and validate that the measurements are water, and not contaminants.

The UPR RockSat 2024 flight will mark the inaugural space application of the Opulent Voice Protocol, an open-source, high-bitrate voice and data protocol, as part of our telemetry system. In addition to being open source, the Opulent Voice's CODEC also incorporates its own forward error correction, which aids in mitigating the risk of data loss. The implementation of this protocol does pose certain risks [2, 3]. During the protocol's development, the Open Research Institute utilized a laptop for signal transmission. In contrast, our approach will employ a Raspberry Pi 4 for data transmission via RF. The emission of RF introduces an additional challenge, as we must ensure that we do not interfere with our payload and the rocket's functionality. If all proceeds as planned, we anticipate being able to transmit data from our payload. For the data collection segment of the mission, we aim to enhance our sensitivity range to what we term 'mid-range humidity', encompassing a sensor measurement range up to 1g/m3, based on data from the 2022 mission. The lessons learned from previous missions have informed us of the necessary sensor exposure required for accurate measurement collection. The 2022 mission observed a change in humidity throughout the flight, validating the concept of detecting varying humidity concentrations at different altitudes. This year, we aim to improve our sensitivity in the mid-range, albeit with the risk of uncertainty regarding whether the measurements are 100% water molecules. Trade studies will be instrumental in limiting any potential sensitivity flaws of the sensor. Additionally, we plan to collaborate with other sensors, such as pressure sensors, to validate known data, and point-contact temperature sensors to calibrate the humidity sensor and limit possible variables during the flight and in data analysis.

Next Steps

One challenge the team has encountered with absorption humidity sensors is their inability to discern whether the measured humidity is H_2O or another compound. The current sensor, a mid-range water vapor presence detector, measures humidity through an absorption process. This method has limitations; if humidity levels fall below 1g/m³, the sensor cannot detect it. Moreover, this invasive process can modify or contaminate the humidity measurement, affecting the sampling.

The ability to measure humidity in sparse environments is crucial, as H_2O molecules become more dispersed at higher altitudes in the atmosphere. To address this, future payloads will incorporate an Axetris TDL (Tunable diode laser) gas analyzer. This device can detect the presence of water and other gases without the need for absorption-based measurements or substance evaporation, thus preserving the sample's physical state.

In addition, we plan to include multiple humidity sensors that would work in tandem with the TDL to create a more accurate humidity profile of the atmosphere [6]. These devices will be utilized in future flights, including the 2025 RockSat-X and RockSat GHOST payloads that will fly into the Aurora Borealis from Andoya Norway. They will also undergo ground testing throughout the year.

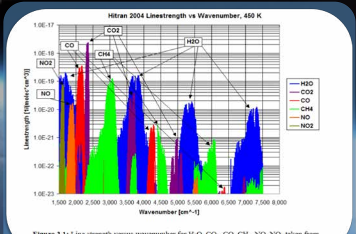


Figure 3.1: Line strength versus wavenumber for H_2O, CO_2, CO, CH_4, NO, NO_2 taken from the Hitran 2004 database at 450 K.

Axetris Tunable Diode Laser Spectrometry (TDLS), enhanced by proprietary technology, is used for the measurement of CH4, CO2, C2H6, C2H2, NH3 and H2O.

Outreach

In collaboration with our partners, museums, and schools across Puerto Rico, we aim to disseminate our data and discoveries. The mission employs two PiCAM 360 cameras to create a virtual reality experience, enabling kids to experience through a Virtual Reality headset that will be introduced to schools. Furthermore, by utilizing the Opulent Voice protocol and voice transmission, we can collect in-flight telemetry from local HAM radio groups for the unique opportunity to compose and transmit a message from space. Moreover, we plan to harness the power of social media platforms to engage a broader audience within Spanish-speaking communities, educating them about the opportunities presented by the program.

References:

[1] D. Jaunches, D. D. Meisel, J. D. Matthews (2001) Icarus, 150 (2), 206-218.
[2] P. Williamson (2022) QSO Today Virtual Ham Expo, [https://youtu.be/9W63MJvxE10]
[3] P. Williamson (2022) QSO Today Virtual Ham Expo, [https://youtu.be/MGXx-TTXylY]
[4] Y. Kawaguchi, S. Yokobori, H. Hashimoto, H. Yano, H. Kawai, A. Yamagishi (2016) Astrobiology 16, 363–376.
[5] N. DeLeon-Rodriguez et al. (2013) PNAS, 110 (7), 2575-2580.
[6] M. E. Leon (2007), US San Diego Electronic Thesis and Dissertations, Diode Laser measurements of H_2O…
https://escholarship.org/content/qt77j1c6nr/qt77j1c6nr.pdf?t=lq6pes

Acknowledgements:

This flight project is funded through NASA Cooperative Agreement 80NSSC20M0052 and flown from the NASA Wallops Flight Facility. This project is the effort of many students that have formed the UPR RockSat team in the present and throughout the years.

NASA Cooperative Agreement 80NSSC20M0052

Opulent Voice at University of Puerto Rico

An Educational Success Story

Oscar Resto is an Instrumentation Specialist at the University of Puerto Rico's Department of Physics. He also serves as the Principal Investigator for the university's RockSat-X program. RockSat-X is a highly-regarded and very successful educational program sponsored by NASA and the Colorado Space Grant Consortium at the University of Colorado at Boulder. RockSat-X offers university and community college teams the opportunity to develop experiments for suborbital rocket flights, fostering innovation and practical experience in space-related fields.

Beyond his academic roles, Oscar is active in the amateur radio community, holding the call sign KP4RF. He has been involved in initiatives such as renewing the Memorandum of Understanding between the ARRL Puerto Rico Section and the American Red Cross Puerto Rico Chapter and has presented to a wide variety of audiences about amateur radio and emergency communications during and after major hurricanes.

The University of Puerto Rico has actively participated in NASA's RockSat-X program since 2011, providing students with hands-on experience in designing, fabricating, testing, and conducting experiments for spaceflight. UPR's RockSat-X team has developed increasingly complex experiments over the years. In 2011, UPR's inaugural RockSat-X project utilized mass spectrometry to analyze atmospheric particles and pressure. Subsequent payloads have continued to evolve and refine the investigation of the "middle atmosphere", an often-overlooked layer in atmospheric studies.

Oscar's engineering design philosophy is to put the program in the hands of the students. The students are fully involved from the beginning of the process until launch. Oscar supports and enables consistent student success in two ways. First, by using the Socratic method of asking questions to lead the students through the many stages of design, test, documentation, and build. Second, by communicating clear expecatations about process and deadlines. Students source parts, build components using a wide range of manufacturing processes, and program all of the control and embedded devices. They carry out testing at the component, module, and end-to-end systems level. The student interface with NASA through meetings and regular reports.

Recent missions included deploying sterilized collection systems into the space environment to gather organic molecules, such as amino acids, proteins, and DNA, from altitudes between 43 to 100 miles above Earth. To ensure the integrity of collected samples, the team implemented innovative decontamination procedures that were carried out in flight.

For the 2023 and 2024 UPR RockSat-X entry, Opulent Voice was included as a communications payload. That version was a 4-ary FSK modulation, voice only, and ran on a general-purpose processor. In 2023, the rocket experienced a failure. In 2024, the mission was a complete success, with Opulent Voice received on a student-built and crewed portable station near the launch site. For 2025, assuming UPR's RockSat-X application is accepted by NASA, the Minimum Shift Key (MSK) version of Opulent Voice, implemented on an FPGA and deployed on a PLUTO SDR, will be used by the student build team. This MSK version is much more advanced and more spectrally efficient.

Review the MSK version at https://github.com/OpenResearchInstitute/pluto_msk
See the student poster presentation about the 2024 UPR RockSat-X project on the previous page.

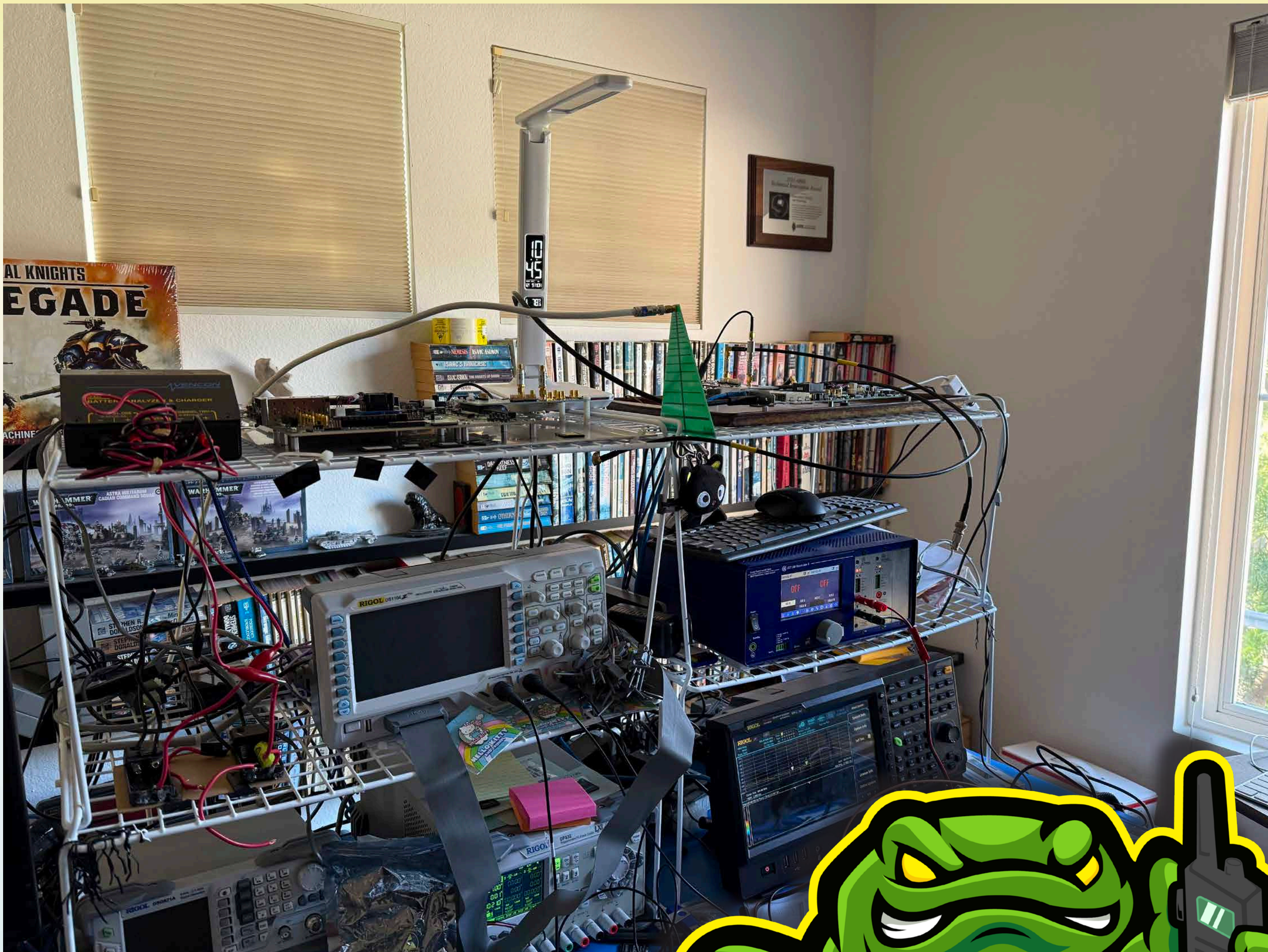
https://www.youtube.com/@OpenResearchInstituteInc

Shipment was delayed, but it has finally arrived. This is the plaque for Ribbit's 2023 Technical Innovation Award.

The metal surface has black lettering and an image of a laptop computer. The body of the plaque is a handsome hardwood. The text reads "For developing the Ribbit app for Android and iOS devices. The innovative and open-source Ribbit app allows amateurs to utilize audio from amateur radio transceivers such as VHF/UHF handhelds to send and receive text messages across the devices. The Ribbit app leverages OFDM technology currently used in cellular 4G and 5G networks & WiFi."

Thank you to Pierre and Ahmet for all the extremely hard work to make Ribbit so successful!

Learn more about Ribbit and try out the web app at https://www.ribbitradio.org



Above, the plaque hanging on the wall in Remote Lab West.

Remote Labs are test benches with spectrum analyzers, oscilloscopes, power and frequency meters, FPGA development stations, power supplies, and multiple SDRs. The equipment is supported by a computer running virtual machines with a variety of operating systems. These VMs support software, firmware, and hardware development. Remote Labs are available 24 hours a day, 365 days a year for open source development.

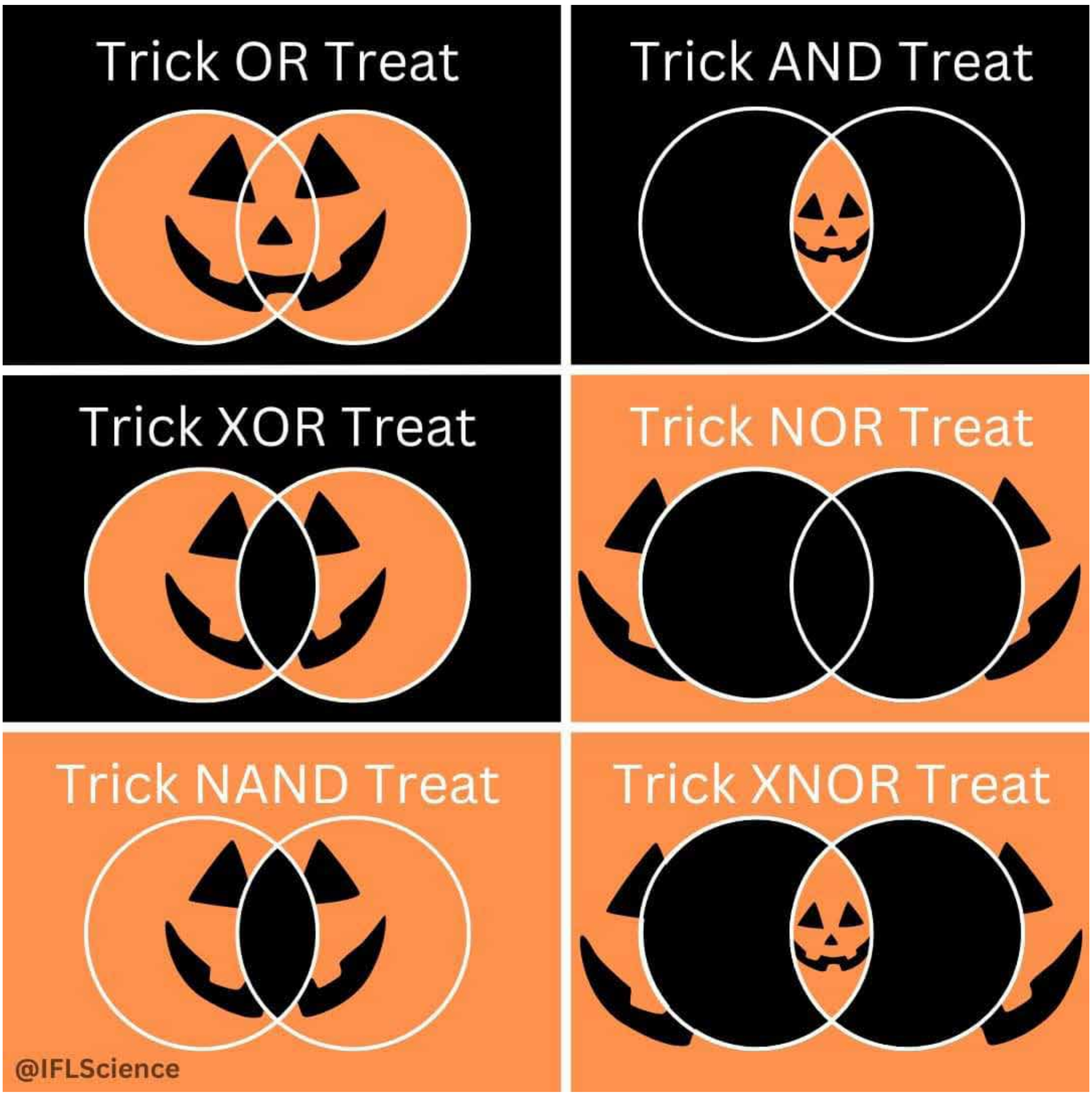
RIBBIT

Geometry Puzzle

Given a 3, 4, 5 right triangle, with an inscribed semi-circle, where the hypotenuse of the triangle bisects the circle to form this semi-circle, find the area of this semi-circle.

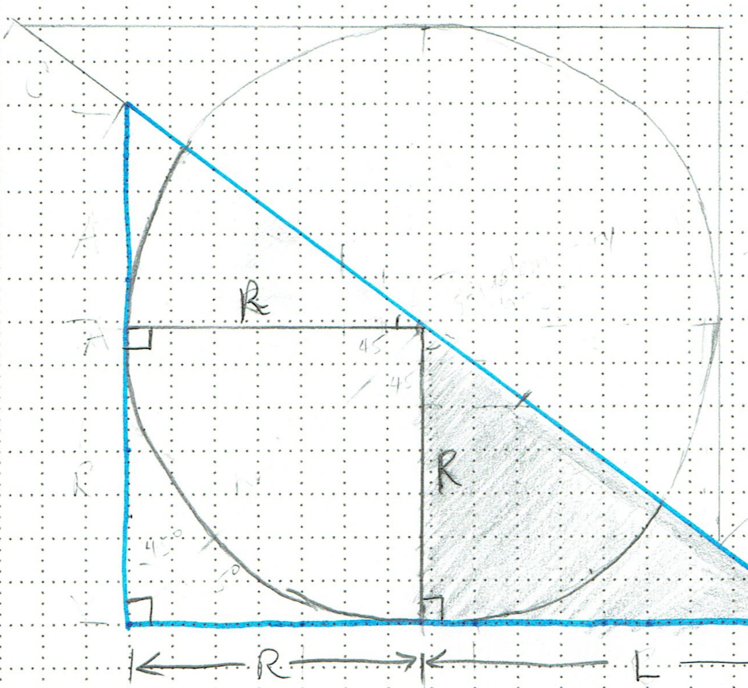
Spoiler! The worked-out solution by Paul Williamson KB5MU is on the next page.

Below, a Halloween Logic Funny that didn't quite make the deadline for the previous issue.



From the workbench of:
Date:

1. Area of a circle = πR^2, so area of a semicircle $= \frac{1}{2}\pi R^2$



2. Any radius of a circle is perpendicular to the tangent at the intersection, so the two radii from the circle's center to the two tangent points form a square.

3. The circle's center lies on the triangle's hypotenuse, so the shaded triangle exists.

4. The shaded triangle shares all three angles with the main triangle, so they are similar, so $\frac{L}{R} = \frac{4}{3}$

5. $R + L = 4$

6. Substituting,

$$\frac{4-R}{R} = \frac{4}{3}$$

(multiply by R) $4 - R = \frac{4}{3}R$

(add R) $4 = \frac{4}{3}R + R$

(simplify) $4 = \frac{7}{3}R$

(multiply by $\frac{3}{7}$) $\frac{12}{7} = R$

$$\text{Area} = \frac{1}{2}\pi\left(\frac{12}{7}\right)^2 = \frac{72}{49}\pi$$

$$\approx 4.6162\ldots$$

The Inner Circle
Sphere of Activity

December 17-22 2024 - Open Research Institute participates on the Federal Communication Commission's Technological Advisory Council (TAC). Working groups composed of volunteers from industry, academia, and open source (ORI) meet weekly and debate and deliver advice to the FCC quarterly. This hybrid meeting is streamed on the FCC website.

December 31, 2024 - Fiscal year ends for Open Research Institute. Work begins on filing 2024 IRS 990 returns, which are due May 15, 2025.

December 20, 2024 through January 6, 2025 - Holiday Break for all labs and teams. March 6, 2025 - Open Research Institute celebrates another birthday with parties planned so far in the US, Canada, and Europe. Sign up for a fun day commemorating open source volunteers around the world by writing hello@openresearch.institute.

Thank you to all who support our work! We certainly couldn't do it without you.

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