

# The Great Hole in the Sky: Solar Eclipse, Radio Science and a Vision for Student Engagement

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## Abstract

The BNL Stars Amateur Radio club has come back to life after an entire generation of absence. We are active in several American Radio Relay League (ARRL) amateur events and NASA data collection activities. We plan to be active and growing our skills until 08APR24.

On October 14, 2023, across the Americas, residents experienced a spectacular eclipse opportunity. As much as it was an incredible cosmic, Keplerian, Sun-Moon-Earth geometric alignment event with potentially significant atmospheric ramifications, many folks felt that it was *merely annular* and just didn't get excited about it. I got excited. I'm excited about sharing science and truth be told, I'm getting to be a little more "radio-active." That's what's got me excited lately.



Fig 1. Time and Date.com Eclipse logo (with permission: Time and Date).

Out here in south central Indiana in the maximum shadow of *la luna* at 17:06 Zulu (Z) time we experienced a drizzly gray overcast sky with hints of a shark-bitten sun (at 49% occlusion) peeking through the cloud cover. Down south in Texas, across the I-10 corridor the landscape experienced near complete occlusion and an annular eclipse. Through two of my STEM teaching and learning networks I'd learned that both the National Aeronautics and Space

Full listing of authors and contacts can be found at the end of this article.

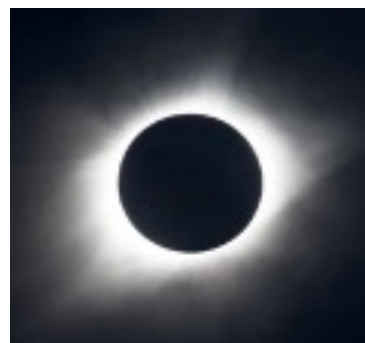


Fig 2. Moments of totality during a solar eclipse. (NASA, 2023, CC 0)

Administration (NASA) and the American Radio Relay League (ARRL) wanted to know more about radio frequency propagation during a solar eclipse and they wanted citizen scientists to be their eyes and ears across the land. My colleagues and I set out to execute a joint venture to collect data for NASA and the ARRL; specifically, whether radio frequency propagation was affected by the passage of the solar shadow (the umbra and penumbra), and if so, which wavelengths are most affected.

We call a radio signal's radiation pattern, propagation. Radio frequency propagation patterns are affected by several technical factors addressed in the appendix. However, one of the key factors is ionospheric reflectivity which is constantly in flux across and around the entire globe. One particularly pronounced diurnal fluctuation comes with "the grey line" as it slides silently across the face of our blue planet turning day into night and hours later night into day. As my wise radio pal

Pete (call sign KA1GHF) says, "...radio wave propagation gets to be kind of incredible *in the twilight zone.*" This eclipse generated twilight zone is the focus of our citizen scientist data collection/investigation.

### NASA's interest

NASA typically works its spacecraft at great distance or completely remote, all via propagating radio waves. They are excited about atmospheric phenomena too. They employ a data collection app for citizen scientists to engage with them, *Globe Observer*. Our middle/high school Civil Air Patrol (CAP) Cadets collected and submitted data to NASA using *Globe Observer* as part of their [CAP Solar Eclipse Mission](#) and will again on April 8th, 2024.



### ARRL's interests

The American Radio Relay League—our national association for amateur radio—gets excited too because atmospheric science is what makes radio transceivers/antennas radiate like they do. ARRL is so excited they put out a call for citizen scientist solar eclipse data collectors, "radio-active" citizens like my amateur radio colleagues and me. They called it the *Solar Eclipse QSO Party* (SEQP) and it encompasses data collection efforts on April 8, 2024, as well. The SEQP is a national (even global) event with hundreds of stations submitting QSO (contact) reports for analysis soon thereafter.

On October 14, 2023, one of the busiest amateur radio days of the year we engaged our local CAP Composite Squadron (GLR-IN-002) cadets, the Bedford North Lawrence Stars Amateur Radio Club (W9BNL) membership, and the local amateur radio community (ARRL Indiana Section) for the event. In all 17 adults, middle school, and high school students gathered at the Monroe County Airport from 14:00 Z to 20:00 Z for our joint eclipse study. Our intent was to measure and report local weather conditions on the quarter hour, sample the 2-meter wavelength (VHF – see terms and definitions below) radio band propagation within line of sight and attempt to reach the Columbus Airport (Bartholomew County, 62 Km/38 miles). In addition, three high frequency (HF) radio stations worked various amateur radio bands (40/20/17/15/12/10 meter wavelength) under the drizzly sky making QSOs (radio contacts) across the USA and as far abroad as Australia, Brazil, Finland, the Slovak Republic, and Canada.

Radio transmission signal strength and signal reports are given on a "clarity and loudness" scale. Clarity

is rated from 5 to 1 and loudness is rated from 9 to 1, so a crystal clear and loud telephone-like signal would be rated at "5 by 9, 5 9, or a 59" while a scratchy, barely heard and barely copyable signal would rate at a "3 by 3, 3 3, or 33." A 4 4 signal is workable, but one must lean in and focus on the transmission. Serious amateur radio is an independent sport, one operator and their transceiver reaching to another operator on their transceiver. Better still, an operator and co-operator working a single transceiver with no extraneous chatter, just focusing on connecting with the operators on the other end of the radio waves. With a cooperating team there is a *mentor* and *apprentice*, a *teacher* and *student*, or the powerful team of a *radio operator* and *data logger/observer* when executing lifesaving tasking or world-wide contesting. When executing critical communications tasking this could be a three-operator team.

During the SEQP our initial reports provided evidence in support of some fluctuations in radio frequency propagation specifically with two stations. On the HF bands Station NØRDF (in ND) whose signal improved greatly from a signal report of "44" hours before occlusion to "59" at maximum solar occlusion and Station NF7E (in AZ) whose propagation AZ-to-IN was strong (59) at maximum occlusion while AZ-to-IN was weak (54). Four hours post-occlusion IN-to-AZ propagation was strong (59) and IN-to-AZ was weak (54).

With the passage of a large east-moving low pressure cell and local weather front, precipitation, wind velocity, and ambient temperature data varied from cool, calm, and dry early in the day to cooler, breezy, and drizzly at midday (maximum occlusion) which would have affected only VHF transmissions. VHF signals are very susceptible to absorption by atmospheric water and earth while HF signals (the lower the frequency the better) may literally pass through a rainforest with little or no measurable signal loss.

### Resurrecting a school radio club (or starting one)

My path to school amateur radio club affiliation with the ARRL began in 2022 at the cajoling of a fellow Ham (amateur radio operator) and CAP Adult Member, Brad (call sign KD9TSY). He and I had been discussing how to grow a stronger emergency communications capability among our CAP squadron's middle and high school cadets. Modern students' experience with commercial radio and cell phones has diminished their understanding of the importance of alternative means of communication and given them a false sense of security for *when the lights go out*, during a natural disaster.

Telephonic device communication is 100% dependent on redundant infrastructure capacity until those back-up systems become overloaded or fail outright. One need only to recall the impossibility of reaching people in the affected areas during 9/11, Hurricane Katrina, or the tornado outbreak of March 31, 2023, that killed three Hoosiers in Sullivan County. Those hard-hit areas had redundant communication systems too, yet without notice they experienced telephone black outs for days, weeks, or months. With no way to prepare themselves those hundreds, thousands, or millions of Americans were left without communication or access to lifesaving public services. Each situation was absolutely tragic and people's lives were in upheaval, completely disconnected from the world with no way to reach loved ones from inside or from outside the catastrophe. An alternative communication method, amateur HF radio transceivers operating on battery/solar power, not infrastructure-dependent cell phones, are an answer to that disconnect.



Fig 4. Tornado outbreak of March 31 - April 1, 2023

Brad and I attended ARRL's June/Summer Field Day to check it out and I got interested. I was reeled in by the beckoning *dahdahdididit dididitdahdah* of the Morse Code key, the mashup of internationally accented

**Food for Thought:**

Monroe County is located in the heart of totality during the April 8, 2024, Total Solar Eclipse. Estimates suggest as many as 300,000 excited visitors and guests will triple the cellular access load and may disrupt this vital communication system.

callsigns drifting across the tent on the warm summer breeze, and the idea of using less wattage than an eco (green) light bulb to reach out to the world. Amateur radio was the answer! I got excited about possible ARRL-CAP connections and got FCC Technician licensed in July of 2022. I met new Ham pals from the Hoosier Hills Ham Club/W9GUS [as in Grissom] (BNL alumni and others) and we resurrected the old Bedford North Lawrence (BNL) High School Amateur Radio Club in August of 2022. The new BNL Stars Amateur RADio and ROCKetry Club became an affiliate ARRL school club in October of 2022. We were now an FCC licensed radio station with one licensed operator, me. How did this happen? I chose the one outreach project that caught my lapel and pulled me in for a better look.

As it turns out, the FCC allows unlicensed persons to operate radios under licensed operator control up to the privileges of the licensed control operator. The club wanted to talk DX (long distance intercontinental) so I studied, tested, and earned the expanded radio frequency band privileges of the FCC General license in December of 2022 as teachers do, over Christmas

Call sign	Worked	Date/Time	Band	Mode	Freq
KC9NVY	PJ2/AC7DC	2023-03-23 00:02:00	20M	SSB	14.22800

Fig 5. Exerpt from W9NVY's Logbook of the world, an ARRL tool.

Break. I didn't have the equipment or the experience to talk to the world on the HF bands until March 23, 2023, when I called and reached Jay (call sign PJ2/AC7DC) in Curacao, off South America, from a picnic shelter in Clifty Falls State Park on 10 Watts of battery power. Now I was talking with the myriad international voices. I was thunderstruck and *electrified* in a good way!

The ARRL offers school club start-up grants and hosts a series of summer teacher technical institutes. To acquire these supports a school club sponsor must become FCC Technician licensed, join the ARRL, and apply for the programs with the help of the good people of ARRL's educational outreach desk. One's initial cash outlay to do all that over one summer can be as little as \$150 with the incredible New Ham Jumpstart program, which provides free handheld radios and study tools. I took advantage of these over Summer 2023 to bring more technology (new radios, antennas, and piles of club training tools) and resources to the club. After TI-1 I studied hard to earn my FCC *Amateur Extra license*, full access to the amateur radio bands, and *much deeper* technical knowledge.



Thereafter the club chose W9BNL as our personalized club callsign (a privilege of the Amateur Extra license) and we got very radio-active. We conducted three Field Day LITE events and got four students on the air during school hours. This year some have stayed on with the club and some have moved on, but we are bigger this year than last year. I am earning my radio chops and we're all learning how to radio in a big way. Kids are talking to faraway places, and I have made QSOs on every continent at odd hours of the day as I learn many lessons to help scaffold their learning. Big antennas are going up on the roof this month. With the help of some Hoosier Hills Ham Club hams (Pete/KA1GFH and Tim/KB9SNL) we are installing the school Ham shack and will assist our new FCC Technicians in setting up their own.

This Fall, W9BNL, the school radio club, really took off. We are twice as many as our first year and a dozen have been on the radios. We are building our skills and learning how to listen/talk to distant operators. Students have soldered and used their own homebuilt VHF antennas, studied electrical (DC series) circuits, conversed with southern Indiana hams via local VHF repeaters and simplex frequencies. On December 15, 2023, we conducted a Parks on the Air activation event at our nearby Spring Mill State. With the help of Jeremy/NQ8M, Mike/W9MDT, and Bryce/KD9YFY, the students made 103 QSOs with local operators as far as CT, FL, TX, WV, and CA. Students also DXed with Canada, Germany, and Switzerland on our tiny battery-powered HF transceiver.

Come the April 08, 2024 solar eclipse our town falls dead center under the longest and widest portion of solar eclipse totality. W9BNL will be on the air to participate in the total solar eclipse SEQP and make electrifying club history.

## Author

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## Terms and Definitions

**ARRL** – The [National Association for Amateur Radio](#)®: An organization of amateur radio enthusiasts dedicated to promoting the appreciation, study, and use of radio frequencies globally for all its varied applications. Here I refer to the US chapter. Some of its applications include watching governmental regulations, community public service and emergency communication, international cooperation, and public service, etc. as well as numerous contesting opportunities.

**FCC Amateur Radio Operator Licensing** - The amateur radio license is a three-tiered, FCC regulated system in the USA. **Technician** (the investigative level) gets operators on the air on the VHF and UHF bands, often with just a \$30 - \$50, pocketable handheld (H/T) radio and their randomly generated FCC callsign (C/S). Techs also have access to low power operation on two HF bands (6 and 10 meters). This first step is a tremendous discovery and learning time while providing some guardrails as one meets hundreds of Hams, discovers basic electrical theory, and attends their first HamFests (imagine a combination swap meet, family reunion, technology conference, and high-end industry trade show all under one giant roof). Discovery of all things radio begins at Technician; what facets of amateur radio interest them, who all *DOES* radio, and how to be a really good (dare I say professional?) amateur radio operator.

**General** (all purpose-level) requires more knowledge of the How-To's of amateur radio practice, safe/wise radio operations, and high-powered radios. General licensure grants operators access to portions of the traditional *short wave (HF) bands* which give operators a longer reach to the world from a simple, long wire antenna. The *General* provides a lifetime of fun and is the goal of many operators.

**Amateur Extra** (the BIG ticket) requires an operator to learn deeper electrical theory, antenna theory, and expects a deeper, more complex (nuanced) perspective of amateur radio operations. It is a badge of honor for some, the top ticket. These operators learn to maximize equipment capabilities and antenna tuning. Some build their own radios, tuners, antennas, etc. With the EXTRA ticket operators are granted access to all of the amateur frequency bands and participate as instructors and evaluators within their peer group. This can lead to career-level understanding of electromagnetic communications systems. Many astronauts, airline pilots, and industry professionals are FCC *Amateur Extra* radio operators.

**CAP – The Civil Air Patrol:** The Civil Air Patrol provides services to communities such as search and rescue, aerospace education outreach, and leadership training for all

ages. They also serve as an auxiliary of the US Air Force. They have a number of programs for teachers (primary and secondary school teacher programs that provide STEM kits and fly the teachers in CAP aircraft) and student participation. CAP offers an excellent classroom STEM resource program for Middle/High School students.

**HF** – High Frequency radio waves between 1.5 and 30 megahertz with wavelengths of 160 to 10 meters are the famous long range frequencies. HF radio waves make the journey between stations by either traveling along the surface of the Earth “ground wave,” or by being returned to Earth after encountering the upper layers of the ionosphere as “sky wave or skip.” The properties of the shortest waves (28 MHz) and the longest (1.5 MHz) waves are unique and produce notably different global propagation patterns. The ionosphere is known to change thickness when activated by diurnal changes in solar radiation levels, hence the inquiries about eclipse totality and radio wave propagation.

**VHF** – Very High Frequency radio waves between 30 and 300 megahertz with wavelengths of 10 to 1 meter. VHF radio waves are referred to as “line of sight” as they can be blocked by geographic features like hills and mountains. When conditions are ideal they also can refract (bend) through the ionosphere and so travel longer distances. FM radio, television, 2-way mobile radio systems like police and fire and hand-held walkie-talkies, all use VHF frequencies.

**The direction of waves** of all types can be changed by both diffraction and refraction. Diffraction is created by the construction and reinforcement of wavefronts after the wave encounters a reflection surface’s corners or edges. Refraction is a more gradual bending of the wave because of changes in its velocity of propagation caused by changes in the medium through which the wave is traveling. HF signals traveling by sky wave are bent through the variably thick ionosphere and then “hop” (reflect) off the ground after ~2500 miles. When conditions are right there can be many ionospheric hops and an operator may even hear the incoming signal arriving via “the long path,” the long way around the Earth from the sending station (Source: ARRL *Amateur Extra Class License Manual*, pp. 10-1 thru 10-4).

**QSO** – An exchange of signal strength information (3 3 to 5 9) and call signs from and to a contact made using radio by radio operators.

**SEQP** – **Solar Eclipse QSO (radio contact) Party:** An event created to provide data for a citizen’s science project to determine the effect of the 2023 and 2024 solar eclipses over the United States on the distances HF and VHF radio frequencies can travel. While VHF is generally “line of sight”, there is evidence that they propagate (travel) longer distances by refracting (bouncing) off the ionosphere

during sunrise and sunset as the longer waves of HF frequencies more typically do. Our solar eclipse experiment is looking at possible extended refraction of the waves and variance in signal reports during eclipse events.

There is previous evidence that the penumbra and umbra may affect the ionosphere in a way that extends radio contacts so we are going to find out!

**Ham**– a term for amateur radio operators. ARRL provides a source for the term here <https://www.arrl.org/what-is-ham-radio>

**Field Day LITE** - *Field Day* is an operational, amateur radio event taking place “afield,” distant and disconnected from buildings and vehicles and operating completely on battery power as practice for our support of civil catastrophes, etc. Field Day includes from one to 12 or more operators during a 24-hour, semi-annual (Winter: January and Summer: June event. There is generally some significant set-up and tear down. W9BNL’s *Field Day LITE* takes place during a 45 minute Friday morning school club meeting session with the assistance of our local Hams and their portable equipment. The Hoosier Hills Ham Club (W9GUS, Tim/KB9SNL, Pete/KA1GHF) and Mike/W9MDT of Greene Cty fame frequently assist with these short opportunities to get our students out of the school building and **On the Air**.

### General terms

**Umbra** – the darkest part of the eclipse where the light of the Sun is totally blocked by the Moon’s presence between the Sun and Earth.

**Penumbra** – the shadowed part of the eclipse where part of the Sun can still be observed. It is the region immediately surrounding the umbra and where Indiana observers were located during the 2017 eclipse.

**Zulu** – also known as UTC (Universal Coordinated Time) or GMT (Greenwich Mean Time). Zulu is the military application of the above and is based on the time at the Prime Meridian which goes through Greenwich, England. Eastern Standard Time (EST) is UTC+5, and it is a 24 hour time scale. So 12:00 midnight for us would be 05:00 Zulu or 05:00 UTC during Eastern Standard Time and 04:00 Zulu for daylight savings time (which we will be on when the next eclipse occurs).

**“The grey line”** – this is the Earth’s terminator or the line where the light meets the darkness at sunrise and sunset. For additional information see [NOAA - Terminator information](#) or [Time and Date’s \(visualized\) terminator tracker](#).

