Level	Investigating Spectrum Users
High School	

Time Required	Lesson Summary
100 minutes (2 – 50 minute class periods)	During this lesson, students will see the radio waves passing through their areas visualized on the screen in the classroom. Next, students will work in small groups to identify the broadcasters of these waves. Lastly, students will work independently to write a persuasive essay about how the spectrum should be shared among users.

Standards Addressed

NGSS

HS-PH4-5 Waves and electromagnetic Radiation. Students who demonstrate understanding can communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

PS4.C Information Technologies and Instrumentation.
Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world and in scientific research. They are essential tools for producing, transmitting, and capturing signals and storing and interpreting information.

Vocabulary	Objectives
Software-defined radio (SDR interference polarization directionality gain coax choke	• Students will identify which industries use the radio frequency section of the electromagnetic spectrum. • Students will be able to explain why the use of the spectrum changes during the day. • Students will develop an opinion on how users should share the spectrum. Then, they will write persuasive essays that convince the readers their solution is valid.

Materials

- RTL-SDR dongle kit https://www.amazon.com/gp/product/B00VZ1AWQA/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&psc=1 (last accessed Sept 20, 2022)

  Or

- https://www.amazon.com/NooElec-NESDR-Smart-Bundle-R820T2-Based/dp/B01GDN1T4S/ref=sr_1_5?crid=1CQ0EN6FXBLUL&keywords=RTL+SDR&qid=1665234340&qu=eyJxc2MiOiI0LjY4IiwicXNhIjoiMy4yMyIsInFzcCI6IjIuOTkifQ%3D%3D&sprefix=rtl+sdr%2Caps%2C97&sr=8-5 (last accessed Sept 20, 2022)

- Download the free technical guide from the website

Pre-Requisites

Students need to know about the electromagnetic spectrum, electromagnetic waves, and how the RTL-SDR dongle works.

Safety Considerations

None

Pacing Notes

This lesson will take approximately 100 minutes. For a teacher with 50-minute class periods, this will take two days.

Day 1 – Scan the spectrum as a class, and students begin to work in small groups to identify known broadcasters.

Day 2 – As a class, identify the unknown broadcasters, students continue to work in small groups to identify known broadcasters, and students work alone on the position paper.

Before the Lesson

Make sure you have set up the hardware and software as described in chapters 1 and 2 of the Windows-based technical guide.

Assessments	Classroom Instructions
Pre-Activity Assessments	Introduction
	While taking attendance, students brainstorm all the devices they have that use the electromagnetic spectrum. After you finish administrative duties, ask students to share things from their list and create a list on the board. To save time, ask students to only share things not already written on the board.
Activity Embedded Assessments	Activities
As one student scans	**Provide Background Information** 1. If you **did not** use Lesson one: Argumentation and radio waves in your classroom, spend several minutes explaining to students how the RTL-SDR dongle receives radio waves. Please discuss the following with your students: interference, polarization, directionality, gain, coax choke, the height of an antenna, and the location of an antenna. It would be best if you made sure students understand these things and their effect on reception. 2. Scanning the spectrum Plug in the dongle and open SDR # **Say:** This antenna receives radio frequency waves in the area. Those waves are invisible, but with the help of this dongle and some downloaded software, those signals are visualized into the image you see on the screen. This image is referred to as a "waterfall." The peaks occur at frequencies where there is a signal. The stuff between those peaks is referred to as "noise." This "noise" can be caused by many things, including bad reception from the antenna and less powerful signals from things such as microwaves. We will learn more about these less powerful signals during this lesson. With SDR# running be sure WFM is selected under Radio. Start at 88 MHz and continue scanning through 108 MHz. Every time there is a peak on the screen click on it and the frequency will appear in the display at the top. Students should record the frequency on their papers. Now click on NFM and scan from 60 to 800 MHz. There will be fewer signals here and you are more likely to see something on the waterfall than hear it. Students can use this page to identify these trunked signals later, https://www.sigidwiki.com/wiki/Category:Trunked_Radio

the spectrum, ask the rest of the class. How is the waterfall being produced? Where is the dongle getting the data? Can we do this without the dongle? Why or why not?	Now click on RAW and scan from 450 to 900 MHz. Like the scan above you will have fewer signals here. However, pause on each screen before you move on as some of these waterfalls are very interesting. When you click on them many will emit a sound which is neither static nor voices. Some of these sounds can be figured out by using this web page, https://www.sigidwiki.com/wiki/Category:Interfering. There are many other frequencies you could explore. The depth you can go to is dependent on the amount of time you are willing to spend. To increase student participation, have a different student come up and perform each scan using your computer.
As students are working, walk around and ask groups. What is your technique for identifying the broadcasters? What was your reasoning for that technique? How would you characterize the users as the frequency increases? Decreases?	**Ask**: Do you recognize any of these broadcasters? (Local radio stations use the frequency in the call sign so students may be able to identify some of the peaks. After the class has scanned the required frequencies, point out that specific frequencies define this section of the spectrum. Therefore there is a limited amount of spectrum available for use. Point out that every peak detected was created by a single broadcaster. Therefore, there can only be a certain number of broadcasters before the broadcasts start overlapping and interfering with one another. 3. Identifying the known users of frequency in the area Government agencies, public safety, and private businesses use radio frequencies to communicate with members of their organization and sometimes with the general public. These frequencies are a matter of public record and can be found on web pages. Hand out the Spectrum Users page and assign students to work in groups of two or three to identify the broadcasters for each frequency. 4. Identifying additional broadcasters

Each time sometimes tries to identify a broadcaster.

Ask: How did you come to that conclusion?

As students are working in small groups or writing alone, walk around.

If students are supposed to be working on the essay but have their heads down or are playing on their computers approach and ask why they aren't working on the assignment. Help those students overcome obstacles so they can succeed in the task.

Ask:

What are you working on right now?

After the majority of groups have identified all published broadcasters, stop all students in their work and turn their attention to the unpublished broadcasters.

Have the groups who are finished identify the frequencies without broadcasters. Allow groups to correct each other. It is possible that a group didn't identify a broadcaster despite that information being published.

It is possible that all peaks in the scans belong to published broadcasters or that the unidentified frequency only had a signal during the evening. If either of those is true, then skip this section.

If there are peaks without published broadcasters, rescan those frequencies. If possible, allow student volunteers to use your computer to do the scanning. Once the frequency has been scanned, have the student click the play button so students can hear what is being broadcast.

Have students share who they believe the broadcaster is until the class reaches a consensus for each frequency. Remember, I don't know is an acceptable answer. Many devices produce low-power radio waves that the SDR may detect. However, those devices do not make an audio signature that can be identified.

After the class has identified all the broadcasters possible

Ask: Where do you think is causing the rest of these peaks?
Ask: What is your reasoning for that answer?

Say: One of the questions on your page directs you to look up the "unlicensed" users of the spectrum. It is likely that some of these peaks can be associated with those sources.

5. Returning to the student page.
   After the class has identified all non-published broadcasters possible have student groups return to the assignment page. They should finish the questions as a group. The students should also discuss the topic for the position paper together, although they should not write it together.

Can you explain how you arrived at that answer? Do you think there are alternative explanations? What do you need me to help you with right now?	
Post Activity Assessments	Closure
	Students will write a position paper on the local use of the radio frequency portion of the spectrum. This assignment will demonstrate that students understand that the spectrum is a limited resource that must be used for various purposes.
Culturally Inclusive/Responsive Components	
At the beginning of class on day two, have students write down their favorite radio stations in town and what they like about that type of music or talk. Then, give students a chance to share with the class. For example, if a student has lived elsewhere in the past, allow them to share radio stations they miss hearing. In those cases, ask students what they liked about that station and if there are ways for them to continue listening.	

Accommodations

If you do not have a way to project your screen on a screen or the wall, you can omit that portion of the lesson. Instead, screenshot the scans and share them with your class.

If you do not have access to student computers, you can print off the pages of local broadcasters. However, to reduce the amount of paper and ink, create a class set instead of printing off copies for each student.

For students with IEPs. Make any changes that are necessary to meet the student's needs. If the research is problematic for these students, have them work in a small group or with an instructional aid on this portion of the lesson.

For students who are ELLs. Make sure the students are in groups with native speakers. This grouping will allow them to understand what they need to do on the assignment.

Educator Resources

Signal identification wiki
https://www.sigidwiki.com/wiki/Signal_Identification_Guide (Last accessed 6/27/23)

Optional Extension Activities

None

Acknowledgments

This is the fifth lesson in a nine-lesson series intended to increase student understanding of radio frequencies. You are welcome to just use this lesson but if you are interested in this topic consider checking out the others in the series.

Lesson One: Mechanical Waves
Lesson Two: Electromagnetic Waves
Lesson Three: Electromagnetic Spectrum
Lesson Four: Argumentation and Radio Waves
Lesson Five: Investigating Spectrum Users
Lesson Six: Aircraft and Newton's Second Law of Motion
Lesson Seven: Weather Forecasting and Radio Waves
Lesson Eight: Satellites and Society
Lesson Nine: Spectrum Management

The creation of the lessons in this series was funded by a generous grant from the National Science Foundation (NSF). The lessons were created as part of the National Radio Dynamic Zone (NRDZ) project at the National Radio Astronomy Observatory (NRAO).