Lesson	Argumentation and Radio Waves
4	
Time Required	**Lesson Summary**
150 minutes (3 – 50 minute class periods)	Students will learn about a device that can receive radio signals in the classroom. They will research methods of improving reception and use that knowledge to create a solution to the problem.

Standards Addressed

NGSS

- Science and Engineering Practices
  - Asking Questions and Defining Problems
  - Engaging in Argument from Evidence
  - Obtaining, Evaluating, and Communicating Information
- 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 scientific research. There are essential tools for producing, transmitting, and capturing signals and storing and interpreting information.

Virginia standards

- PH.1.b The students will demonstrate an understanding of scientific and engineering practices by defining design problems that involve the development of a process or system with interacting components and criteria, and constraints
- PH.1.c. The student will demonstrate an understanding of scientific and engineering practices by interpreting, analyzing, and evaluating data.
- PH.1.d. The students will demonstrate an understanding of scientific and engineering practices by constructing and critiquing conclusions and explanations. They will construct arguments or counterarguments based on data and evidence.
- PH.5.b Students will understand that the long wavelength, low-frequency portion of the electromagnetic spectrum is used for communication.

West Virginia

- Students will design a solution to a complex real-world problem by break it down into smaller, more manageable problems that can be solved through engineering.

Vocabulary	**Objectives**
1. Interference 2. Polarization 3. Directionality 4. Gain 5. Coax choke	• Students will be able to understand a problem and work collaboratively to create and test a solution. • Students will be able to provide evidence from research and data analysis to support their claims.

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 be familiar with the electromagnetic spectrum.

Safety Considerations

None

Pacing Notes

This lesson is expected to take 150 minutes or three 50-minute class periods.

Day 1 – Review the electromagnetic spectrum, introduce the radio frequencies, talk about the RTL-SDR dongle, put students in groups and go over the directions.

Day 2 – Student research, design, testing, redesign

Day 3 – Students finish their presentations, presentations given, and whole class discussion.

Before the Lesson

Follow the instructions in chapters 1 and 2 of the technical guide to set up the RTL-SDR dongle in your classroom. Select the location with the worst reception as the placement for your hardware.

Print out the student research pages.

Assessments	Classroom Instructions
Pre-Activity Assessments	*Introduction*
If only a few students offer to answer, call on others to determine their level of understanding. If students don't seem to remember any meaningful information about the spectrum, go back and reteach.	**Say:** Recently, we learned about the electromagnetic spectrum. Who can remind us of something we discussed during that lesson? Allow several students to share. Some may remember a lot, while others only remember one fact. Allow students to correct the information a classmate provides as long as they do so respectfully.
Activity Embedded Assessments	*Activities*
	1. Radiofrequency **Say**: During the previous lesson, we focused on the entirety of the electromagnetic spectrum. Today's lesson will focus on the Radiofrequency portion of the spectrum. Display a picture of the spectrum and point to the radio frequency portion. Some diagrams are found in the electromagnetic spectrum lesson, which can be found in the K-12 curriculum section. **Say**: This portion of the spectrum is used for various purposes, including radio astronomy, military communications, Bluetooth, and cell phone communications. To make the management of this section of the spectrum easier, it has been broken down into bands based on frequency. Show students the radio frequency bands document. There you will find a table that lists one way of breaking the frequency into bands. It also gives you the wavelength, and some example uses for each band.

Ask: How are wave frequency and wavelength related? Students should be able to articulate that when the frequency is higher, the wavelength is shorter. The inverse is also true.	Help students understand the wavelength range from the biggest to the smallest radio waves. For larger wavelengths, make comparisons between the wavelengths and distances they are familiar with. For the smaller wavelengths, find an object which is approximately the same size. 2. RTL-SDR dongle **Say**: This is an RTL-SDR dongle. RTL just specifies the type of chip that is inside the dongle. SDR stands for software-defined radio. With the help of an antenna, this dongle can intercept a portion of the radio frequencies. The antenna receives the signal from the air. The dongle then changes the signal into a series of numbers analyzed by a software package. Finally, that software produces an image representing the data collected by the system. See the educator resource section in this guide for more information. Perform a scan using SDR# and project the results on the screen. Explain to students what they see on the screen. Point out the "noise" which is caused by bad reception. **Say**: Your challenge is to research aspects of an antenna that can affect reception. Assign students to groups of three. **Say**: As I pass out these papers, discuss in your group what common qualities of an antenna could affect reception. Pass out the papers and give students a minute to read through them. **Ask**: Are there any questions about your instructions?
Be sure that in addition to listening to questions, you are also looking for groups that seem lost. After students have begun the research go over to those groups and **ask**: What are you	**Say**: Remember you are designing a solution that improves the reception. The constraint for your design is that it must use one of the antennas provided in the kit. In addition, you may use items you bring from home to augment that antenna. The criteria is that the reception improves, which means less noise. If your group works quickly, you will have time to test your solution and redesign it according to your test results. Finally, at the end of day three, your group will present your solution to the class and test it. During that presentation, you must have a reason for every decision you make, supported by evidence.

supposed to be doing? **Ask**: Then what are you going to do? **Ask**: Why are you doing this? By asking these questions, you will be able to determine if the group understood the paper you handed out.	
As students are working, walk around and **ask:** What are you doing right now? How will that help you with the next step? How are the three of you collaborating on the research? What can I help you with at this moment? What evidence guided that decision? What alternatives are you considering?	3. Student research, solution creation, testing, and redesign Students should divide the concepts on their pages between themselves and start researching. To keep students from taking too long on the research, you may want to set a time limit for that portion of the project. Also, explain to students how you want them to transition from one component of the project to the next. For example, will you allow them to move at their own pace, or does your class need a more controlled approach? **Alternative to internet research**. If your school does not have computers for students to use, you can print out research materials ahead of time.
Try not to ask many questions during the presentations. Instead, let students ask the	4. Presentations Before you start group presentations, discuss the right and wrong way to challenge another student's answer. See the teacher resource section for some articles that offer suggestions. When a group presents, they should discuss their solution, providing reasoning for

questions and let the group respond. As groups are presenting, pay attention to all members. Does everyone seem engaged in the presentation? Were they all part of the solution? Also, pay attention to the audience. Is everyone paying attention? Is anyone sleeping or on their phone? If so, try using proximity to get them to have the correct behavior. For example, do all the students who have questions get to ask them? If a student doesn't get to ask their question, stop the presentations and allow that person to speak.	each choice. Other students should be allowed to challenge aspects of the solution during this time. The presenting group should be able to justify their choices with additional evidence. After the solution has been discussed, then the group should test their solution. It would be best if you took a screenshot of each test so the solutions could be compared at the end of the presentations. At the end of the presentations, go through the screenshots. Have the class vote on the solution they thought most improved reception. If there is disagreement in the class, have them talk through it. Require students to provide reasoning for their answer. Ultimately, you want to have the solutions ranked from best to worst.
Post Activity Assessments	*Closure*
During this discussion, try not to assess their answers. Instead, allow their peers to control the quality of responses by asking for reasoning and clarification. It is crucial to allow students to work through this process. Only intervene when	Whole class discussion After all, the presentations have been finished, guide the class through the following discussion. These questions are to get you started; add additional questions as you deem necessary. **Ask**: Was there one element that was repeated in most designs? **Ask**: Why do you think many people chose to include that in their designs? **Ask**: Is there any evidence that the element was important in improving reception? **Ask**: Did the three best designs have anything in common? **Ask**: What separated the best design from the rest? **Ask**: Why do you think that element was so effective?

necessary to remove a misconception embedded in the discussion.	**Ask**: If you could do it again, what would you do differently?

Culturally Inclusive/Responsive Components

Be aware that students from certain cultures, for example, Vietnam, may be uncomfortable speaking up in a group. Be cognizant of that when putting students in groups. If you have one or more students who have demonstrated reluctance to speak up in previous groups, pull them aside before class. Ask them if there are students they would feel comfortable talking to in a small group. If the request is reasonable, allow them to work with those students. See the educator resources section for an article on this topic.

Be sure to tell students that they cannot go out and buy things to bring in as additions to their antennas. If students are given this ability, inequality will develop between groups depending on their economic background. Students should only be allowed to bring in pieces of metal (such as a cookie sheet) to put under the antenna or perhaps a magnet to wrap the coax choke around. If you would rather avoid students bringing in things, simply make the appropriate materials available.

The following individuals are important figures in antenna engineering.

- Heinrich Hertz – a German scientist who discovered radio waves. https://nationalmaglab.org/education/magnet-academy/history-of-electricity-magnetism/pioneers/heinrich-hertz (last accessed May 2022)
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- Karl Jansky – American Scientist who discovered radio waves in space. Known as the father of radio astronomy. https://nationalmaglab.org/education/magnet-academy/history-of-electricity-magnetism/pioneers/karl-jansky (last accessed May 2022)
- Yang Hao – Dean of Research in Science and Engineering at Queen Mary University in London. He develops antennas made of unique materials that are designed to reduce interference, cost, and weight. http://www.eecs.qmul.ac.uk/~yang/ (last accessed May 2022)
- Mohamed Sanad – An engineering professor in Egypt. He has developed a new internal antenna for cell phones that allows them to work on all frequency bands.

Accommodations

The research portion of this activity may be difficult for students who struggle with reading. Some suggestions include identifying web pages with a lower reading level in advance. Then, provide those links to the student (s) privately, so you don't embarrass them. Alternatively, you could allow those students to work on the research in a resource room.

Some students don't work well in groups. If you have a student who works best alone, please allow it if you have the space for the student to sit by themselves and time for an extra presentation.

Educator Resources

What is SDR?
S = software, D = defined, R = radio.
A software-defined radio can be defined differently. In this lesson when we refer to SDR, we mean a device that processes radio frequency waves with software. There are two main components; one converts the radio waves, and the other processes the information in the waves.
What does RTL stand for?
RTL is not an acronym. It is simply the type of chip that is included in the dongle. The dongle contains an RTL.2832U chip. This chip was included in dongles initially designed to convert analog tv signals to digital. However, it was also found that this chip allowed the dongle to act as an SDR.

How does the RTL-SDR dongle work?
The dongle uses an antenna to receive radio waves traveling through an area. The antenna receives the signal, which is changed into "a sequence of numbers representing the value of the signal at regular time intervals." This data is then analyzed through software to produce an output.
Sources
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https://www.teachthought.com/critical-thinking/sentence-stems-higher-level-conversation-classroom/ (last accessed May 2022)
https://www.apsva.us/wp-content/uploads/2020/03/Discussion-Skill_Sentence-Starters.pdf (last accessed May 2022)

https://hbr.org/2014/07/learning-to-speak-up-when-youre-from-a-culture-of-deference (last accessed May 2022)

Optional Extension Activities

None