Level	The Uses of Radio Waves and Frequency Allocation
High School	

Time Required	Lesson Summary
5 – 50 min. class periods (250 min.) 2 – 50 min. class periods (100 min.) without the research project.	This lesson describes the extensive uses of radio waves, which are not well understood by students. They will learn that radio frequencies have numerous applications, and require government regulation to prevent interference and unfair competition, and they will have a chance to investigate their own questions regarding radio.

Standards

NGSS

HS-PS4-2 Evaluate questions about the advantages of using a digital transmission and storage of information

HS-PS4-5 Communicate technical information about how some technical devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy

Vocabulary	Objectives
Frequency, Wavelength, Hertz, MHz, GHz,	• Students will be able to communicate the many uses of the radio spectrum, including with personal devices like phones and laptops. • Students will understand how the spectrum is shared between its many users, and evaluate the advantages and disadvantages in a growing field of technology.

Materials

- Students will need access to internet-enabled devices for research
- Chart or butcher paper and markers for groups
- Radio Frequency Allocation Chart – There are three options for obtaining this resource. 1) You can order it for $16 each and free shipping at, https://bookstore.gpo.gov/products/united-states-frequency-allocations-radio-spectrum-poster (Last accessed 6/12/23). 2) It can also be downloaded here,

https://www.ntia.doc.gov/files/ntia/publications/january_2016_spectrum_wall_chart.pdf (Last accessed 6/12/23). 3) The puzzle pieces document has the chart broken down into piece sizes that can be printed and cut out. Since the poster is large (36"x48") with some small print, purchased posters are recommended. If possible, purchase at least two so there is a second poster for reference or backup parts.

- Optional: Magnets or tape to hang the cards on the wall, or make a clothesline with string and clothespins. (These are usually still available at local dollar stores.) Be sure there will be enough space and materials for all the cards. If tape is being used, be sure it will not damage the cards, or else have the cards laminated beforehand.

Pre-Requisites

Students should have completed an introduction to waves, frequency, and the electromagnetic spectrum.

Safety Considerations

None

Pacing Notes

Day 1 – Read an article, radio frequency allocation clothesline sort,
Day 2 – Technology and Radio Frequency Use activity, Producing questions on the radio spectrum

Can stop the lesson here.

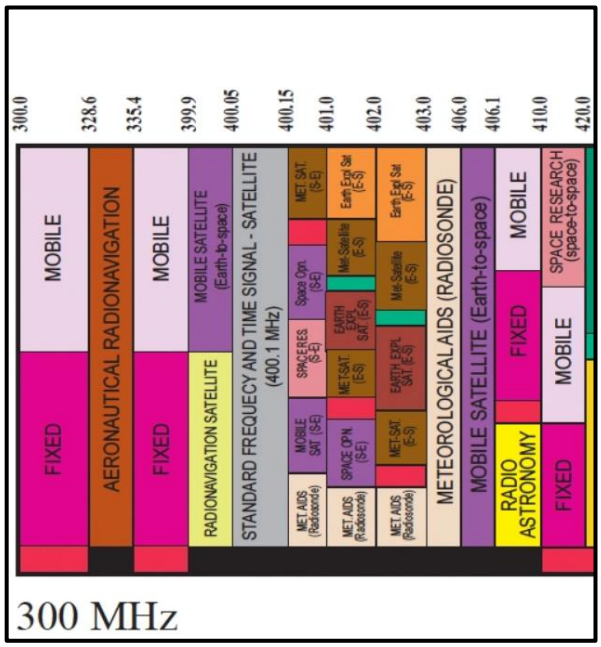
Day 3 - research
Day 4 – create presentations
Day 5 – class presentations

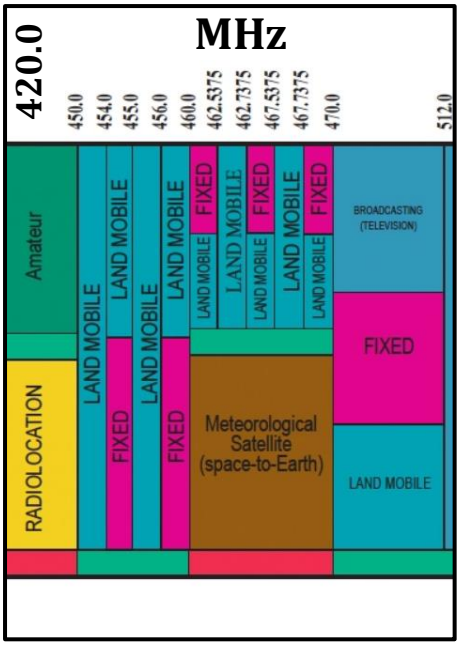
Before the Lesson

1. Print the following handouts for each student:
    a. Radio Frequency Allocations
    b. Optional Worksheet: Technology and Radio Frequency Use

2. To prepare the Radio Frequency Allocation Chart cards, teachers will need to cut the Radio Frequency Allocation Chart mentioned in the Materials section above into sections for the activity. Order the poster ahead a few weeks ahead of time.

a. Cut the spectrum part of the chart into sections. Allow the cards to vary in length, as some parts of the spectrum are very simple over a long range and some sections are very complex. Be sure the frequencies at the top of each section are included in the cards so students can place them back in order during the activity. <u>You will have to write in the units by hand for each card where it is not apparent already.</u> If your students need extra scaffolding, you may need to copy the frequencies so that the end of one card and the beginning of the next card both have visible frequencies, but this should not be necessary for all students. Teachers can use their best judgment regarding the level of their classes. See the example below.





The unit, "MHz" was written at the top of the second card to make the units apparent. The initial frequency of "420.0" was copied to the second card so both cards show the correct starting and ending frequencies.

3. Teachers can choose to laminate the pieces so the cards last a long time.

Assessments	Classroom Instructions
Pre-Activity Assessments	**Introduction**
	1. Quickwrite Warmup/Bellringer: *With all the devices around we use every day, do you think there is a limit to the frequencies we have available?* a. Have this writing prompt on the board as students enter the

As they work, walk around and give feedback to correct and incorrect answers. Students can turn bellringers weekly or they can be checked with notebook checks. Teachers can try using stamps as positive feedback for thoughtful answers that add more points to the grade.	classroom. b. Allow students about 5 min. to answer on their papers, in their notebooks or on loose leaf paper. c. When time is up, have the class share their answers. d. Follow up with the class by asking whether they have ever experienced interference on a device, such as a key fob not working for a car or a baby monitor picking up signals from a neighbor.
Activity Embedded Assessments	**Activities**
	Day 1 1. Article - "Our gadgets increasingly crowd the radio spectrum. They're crowding out science too" https://laptrinhx.com/news/our-gadgets-increasingly-crowd-the-radio-spectrum-they-re-crowding-out-science-too-q1dr37p/amp/ (Last accessed 6/14/23) a. Have the students read the article either individually or in small groups. Alternatively, you can read the article aloud to them. b. The teacher can ask questions such as: What were the types of research mentioned using radio waves? What were some of the devices causing interference? What was a proposed solution to all the interference? What was the main idea of that story? 2. Radio Frequency Allocation Clothesline Sort a. **Say**: Radio frequencies are a very valuable commodity allocated and monitored by the Federal Communications Commission like real estate on a Monopoly board. Let's see just how much space we have in the radio frequency range. In a moment we will get into groups to investigate how the radio spectrum is divided up, but first, we need to understand our roles in the groups.

	b. Pass out the activity worksheet, Radio Frequency Allocations, included with this lesson. Remind them to stop and listen to the directions before working ahead of everyone. c. **Say** At the top right side of your sheet you will see the group member jobs. The **Reader** is in charge of reading and understanding the numbers on the cards. They will know how to put the frequencies in the correct order. The **Runner** will be the only student in the group who can get out of their seat. They will place the cards on the wall or get supplies as needed. The **Speaker** will say the directions out loud for the group as you work through the questions. They are also the one person in the group who can speak loudly for the group. Finally, the **Captain** is in charge of the team and keeping everyone in line. They make sure all are participating and follow the rules of their job. Keep in mind some people may need to take on more than one job if your group is smaller than four people. Are there any questions? c. Allow the teams to calmly get into groups of 3-4. They can begin to fill out the Group Members and Jobs section on their page. d. Once the groups are settled, indicate to the class that the Speaker can read the Objectives and Pre-Activity for their group when they are ready. e. When the class is ready to move on, display the US Radio Frequency Allocation chart, https://ntia.gov/sites/default/files/publications/january_2016_spectrum_wall_chart_0.pdf Note that this chart includes radio waves as well as what they might consider microwaves. You can ask the class at this point if they notice anything about the chart at first glance. Review the unit for frequency, Hertz, and the prefixes seen in the chart, KHz - thousand Hz
While students are reading walk around looking for distracted individuals. Proximity	

will help manage behaviors in this situation.	MHz - million Hz GHz - billion Hz f. **Say:** Now in a moment, I will pass out cards to each group. These cards were cut from this chart and show the activities allowed at that range of the electromagnetic spectrum. Make sure everyone in your group can see the frequencies on each card. The Reader from each group will put the cards in order of lowest to highest frequency. Readers, be sure to explain to the group out loud how you can tell which card has a higher or lower frequency, and pay attention to the units, such as Megahertz or Gigahertz.
Walk around and check on the groups as they work, asking questions such as, "Which is bigger, Gigahertz or MegaHertz?", and checking to make sure all students in a group can explain the process for sorting the cards.	g. Pass out the US Frequency Allocation Chart cards as evenly as possible to each group. These cards should be from various sections of the spectrum and of varying difficulty. As the groups receive their cards, remind them that all members of their group should be allowed to read them, and the Reader should kindly explain to their teammates how they can determine the order of their cards from low frequency to high. When they have sorted the cards, proceed with the next step. h. **Ask:** What are some of the uses you are seeing in your cards for radio waves? i. Allow students to call out answers and write them on their papers in Part 1. Provide clarification on activities they might have heard of but are not known to everyone, such as "aeronautical radionavigation", "fixed", and "amatuer". j. The teacher can display the Radio Services Color Legend after students are done volunteering answers. Clarify any questions they may have before moving on. Especially have the students notice the activities they use in everyday life, like phone service and GPS. Inform the students that mobile companies, like Verizon and AT&T pay BILLIONS OF DOLLARS to gain access to very small but ideal sections of the frequency range (see this article for more information). k. Before the class arranges the whole spectrum in order, be sure to explain the clothesline activity clearly. You can prepare the area where the cards will be lined up ahead of time to show where KHz starts, MHz, etc. It will help to minimize chaos if the beginning of the spectrum is done with

guidance as an example.

l. **Say:** Everyone has cards from different parts of the radio spectrum. We will now put our cards up on the wall in order of lowest to highest frequency to see how long this spectrum is altogether. Let's see which group has the card with the lowest frequency! Who has 0 kHz?

m. The group with the 0 kHz card will send their Runner to put the card on the wall. Ask the Runner what is the ending frequency on their card, and repeat that frequency so the class can hear. Let the first runner return to their seat. See which group will have the next card in the sequence, but do not have them run the card to the wall yet.

Note: The class can complete the activity in the classroom on the wall/board or, with permission from an administrator, take the activity to the hallway or another large area if the class understands how to behave. If there are lockers lining the hallways at school, students can use magnets to hold their cards in place. Otherwise, use tape or make a clothesline with enough clothespins for the number of cards. In total, the clothesline will probably be more than 20 feet long! The teacher can hang multiple rows so there is enough room for all the cards, but be sure the students understand the order of the frequencies placed in multiple rows.

n. **Say:** Before we finish hanging our cards, let me repeat the expectations. I will say the frequency we are on out loud for the class to hear. The teams, especially Readers, will listen and see if they have the next card. If your team has that card, you will send your Runner with the card so we can hang it up. I will check and if it is the correct one, I will read out the next frequency. Remember, only the Speaker of your group can speak louder than a whisper for this game, and only the Runner can walk around. Captains should be making sure everyone is on the right task. Does anyone have any questions?

o. Answer any questions or add any instructions as needed for the class, such as if the class will move outside of the classroom. Announce the next frequency again for the class, and continue the game until all the cards are in order.

	p. **Say:** Great job, everyone. What are you seeing about the radio spectrum that you didn't know before? q. Allow students to respond to this question out loud regardless of their jobs within their groups. Point out any interesting uses on the spectrum that they may not have noticed earlier, and ask questions about their interpretation of the busier parts of the spectrum. "Why do you think this area is so crowded?" Have volunteers help take down the cards if needed, and have the students complete the rest of their worksheets. 3. Conclusions a. Have students respond to this question where they normally write exit tickets or on sticky notes to turn in as they leave. What were the main ideas about what we learned today? What is one new fact you learned? **Day 2** **Optional Worksheet: Technology and Radio Frequency Use** Allow students about 5- 10 min. to answer. As they work, walk around and give feedback to correct and incorrect answers. When most are finished, have the class share their answers.
.	**Optional Worksheet: Technology and Radio Frequency Use** Allow students about 5- 10 min. to answer. As they work, walk around and give feedback to correct and incorrect answers. When most are finished, have the class share their answers. **Activity 3:** Producing Questions on the Radio Spectrum (~25 min.) Have the students get into their groups if they are not already there. Keep the groups the same as they were in the last activity so

	the students can continue in the same job roles. Open the Formulating Questions slides for the class. Explain to the students that they are about to do a brainstorming activity with their groups. Remind them of their job roles, and point out that for this activity the Reader will now become the Writer for the group's chart paper. Allow the class time to read slide 2 and ask any questions before moving on. Proceed to slide 3 and explain the rules of this activity. Explain to them that it is vital they keep the classroom a safe space for any questions appropriate for the activity. Creative questions are appreciated. Everyone in the group should be participating. Additionally, they should allow the Writer to write out each question before moving to the next one. Review the rules written out on the slide, and then let the teams get their supplies before starting. When the class is ready, move to the prompt slide. Give the groups 2 - 3 minutes to fill their chart paper with as many questions as they can. Some groups may need more than one chart paper. Encourage them to keep working for the whole time. For the next step, the students will now categorize their questions as either closed or open-ended. They can write a "C" or "O" next to the questions. Following that, they will next choose 3 close-ended questions to change to open-ended, and vice versa. This step may be difficult for some students, but encourage them to try. Walk around the room to see how they are doing so far. Next, the teams will now pick their top three favorite questions from their list and will prepare to discuss. The Speakers should be prepared to talk for the group and explain the thinking process for how they came to their results. Teachers can continue the discussion, and have the class notice any patterns they see in what questions each group chose, elicit clarification questions, and have other teams offer additional ideas to the speaking groups. After discussion, move to slide 8 and explain the research project. Students will choose one of their questions from their group's chart to research, but direct students toward questions that ask about the uses of radio, the allocation of radio, the future of radio signals, or other questions that are meaningful to explore in science class. The teacher can decide whether students must work with the whole group on one project or split into smaller groups/individuals. Make it clear they are being graded on the amount of investigating and preparation

	they do for this project. Have the students list out on the board what they are going to do their projects over so that no two projects will be overly similar. Once the class is clear on the directions, have them use the Project Development Worksheet as they research their question. This worksheet can be completed online or on paper. **Activity 4:** Project Research and Presentation (1-2 class periods, ~180 min.) Teachers can determine how the presentations will be graded. To save time, presenting to the class can be on a voluntary basis for extra credit, or the class can view projects posted online as a part of class time. Have check-ins for each group/project to make sure they are on track and understand the assignment.
Post Activity Assessments	**Closure**
	Exit ticket: One thing I learned and one thing I still have questions on.

Culturally Inclusive/Responsive Components

Students will have opportunities to share personal experiences and opinions with this lesson. Students are working in groups and taught that each person's input is valued. Further study of historical pioneers of radio can include lessons on underrepresented figures including Hedy Lamar, the inventor of frequency hopping as signal encryption, and Gladys West, a mathematician and developer of GPS.

Educator Resources

Acknowledgment

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Below is a list of the lesson titles included in the series. All lessons can be accessed from this web page, https://superknova.org/educational-resources/.

Middle School

Introduction to Satellites
Weather Predicting
Introduction to Radio Wave Communication
The Importance of Radio Astronomy
Cubesat Model Building
Understanding FM Radio
Radio Frequency Technology
Who Decides if You Get 5G?

High School

The Uses of Radio Waves and Frequency Allocation
Is Radio Technology Safe?
Diffraction of Radio Waves
Measuring Sea Surface Temperatures with Satellites
Marine Animal Tracking and Bathymetry
How to Design Your Own Crystal Radio
How Radio Waves Changed the World
Simple Wireless Communication
Seeing and Hearing the Invisible
Local Wireless Radio Frequency Communication
Investigating the Internet Connection
The Geometry of Radio Astronomy

Informal

Modeling Radio Astronomy