

Level	<h1>The Uses of Radio Waves and Frequency Allocation</h1>
High School	
Time Required	<b>Lesson Summary</b>
~270 min.  (~90 min. without research project)	This unit describes the extensive uses of radio waves, which are not well understood by students. They will learn that radio frequencies have numerous applications, require government regulation to prevent interference and unfair competition, and they will have a chance to investigate their own questions regarding radio.
<b>Standards Addressed</b>	
<p><b>Texas</b></p> <p>Knowledge &amp; Skill Statement - P.3: The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:</p> <ul style="list-style-type: none"> <li>● Student Expectation - P.3B: Communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials.</li> <li>● Student Expectation - P.3D: Research and describe the connections between physics and future careers.</li> </ul> <p>Knowledge &amp; Skill Statement - P.7: The student knows the characteristics and behavior of waves. The student is expected to:</p> <ul style="list-style-type: none"> <li>● Student Expectation - P.7C: Compare characteristics and behaviors of transverse waves, including electromagnetic waves and the electromagnetic spectrum, and characteristics and behaviors of longitudinal waves, including sound waves.</li> </ul>	
Vocabulary	<b>Objectives</b>
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. They will also understand how the spectrum is shared between its many users, and evaluate the advantages and disadvantages in a growing field of technology.
<b>Materials</b>	
<ul style="list-style-type: none"> <li>● Students will need access to internet enabled devices for research</li> <li>● Chart or butcher paper and markers for groups</li> </ul>	



- Radio Frequency Allocation Chart - This chart can be ordered for \$6 each and free shipping at, <https://bookstore.gpo.gov/products/united-states-frequency-allocations-radio-spectrum-poster>. It can also be downloaded here, [https://www.ntia.doc.gov/files/ntia/publications/january\\_2016\\_spectrum\\_wall\\_chart.pdf](https://www.ntia.doc.gov/files/ntia/publications/january_2016_spectrum_wall_chart.pdf). 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 if desired, 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

This lesson was written to take about 270 minutes when including the research project and preliminary question generation activity. Without the project and questioning activity, this lesson will take about 50 minutes.

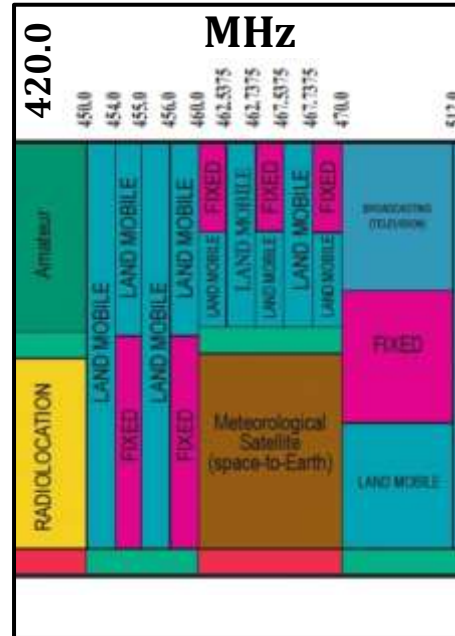
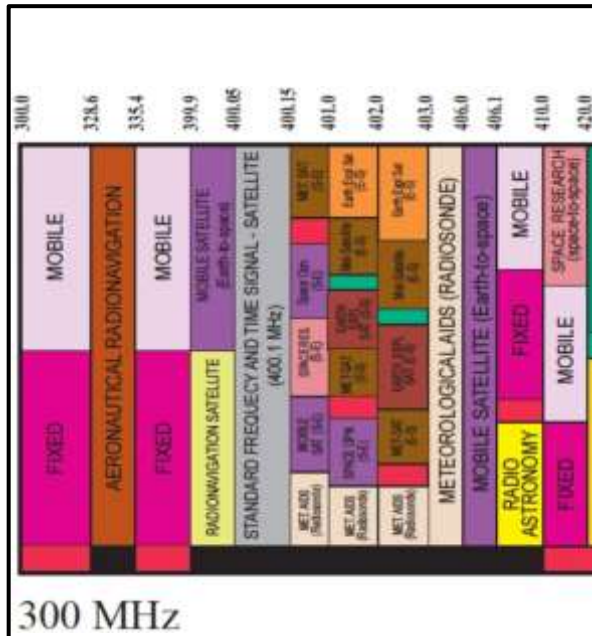
### Before the Lesson

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

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. You will have to write in the units by hand for each card where it is not apparent already. 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.

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

Assessments	Classroom Instructions
Pre-Activity Assessments	<b>Introduction</b>
Students should already be familiar with electromagnetic waves and the spectrum as well as the properties of frequency and	<p><b>Quickwrite Warmup/Bellringer:</b> <i>With all the devices around we use every day, do you think there is a limit to the frequencies we have available?</i></p> <p style="text-align: center;">Have this writing prompt on the board as students enter the classroom. Allow students about 5 min. to answer on their papers, in their notebooks or on loose leaf paper. As they work, walk around and give feedback to correct and incorrect answers. When time is up,</p>

wavelength.	<p>have the class share their 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.</p> <p>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.</p>
Activity Embedded Assessments	<b>Activities</b>
	<p><b><u>Day 1</u></b></p> <p><b>Activity 1:</b> NPR Article/Podcast - “Our gadgets increasingly crowd the radio spectrum. They’re crowding out science too” (15 min.)  <a href="https://why.org/segments/our-gadgets-increasingly-crowd-the-radio-spectrum-theyre-crowding-out-science-too/">https://why.org/segments/our-gadgets-increasingly-crowd-the-radio-spectrum-theyre-crowding-out-science-too/</a></p> <p>Play the podcast for the class to hear. Be aware the article is not a script, and does not follow the audio exactly. The students might need the teacher to pause the audio periodically to emphasize points or ask questions as it plays rather than playing the whole way through.</p> <p>The teacher can ask questions such as,</p> <ul style="list-style-type: none"> <li>● “What were the types of research mentioned using radio waves?”</li> <li>● “What were some of the devices causing interference?”</li> <li>● “What was a proposed solution to all the interference?”</li> <li>● “What was the main idea of that story?”</li> </ul>
	<p><b>Activity 2:</b> Radio Frequency Allocation Clothesline Sort (~30 min.)</p> <p><b>Say:</b> <i>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.</i></p> <p>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.</p>

**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?

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. 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.

When the class is ready to move on, display the US Radio Frequency Allocation chart, [here](#). 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

MHz - million Hz

GHz - billion Hz

**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.

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. 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. When they have sorted the cards, proceed with the next step.

**Ask:** *What are some of the uses you are seeing in your cards for radio waves?*

Allow students to call out answers and write them on their papers in Part I. Provide clarification on activities they might have heard of but are not known to everyone, such as “aeronautical radionavigation”, “fixed”, and “amatuer”. 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).

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.

**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?*

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.

**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?*

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.

**Say:** *Great job, everyone. What are you seeing about the radio spectrum that you didn't know before?*

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.

**Optional ticket out the door:** 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:** (If the class is on a block schedule, this is still Day 1.)

### **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 open ended questions to change to closed 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





	<p>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.</p> <p>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.</p> <p><b>Activity 4:</b> Project Research and Presentation (1-2 class periods, ~180 min.)</p> <p>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.</p>
<p>Post Activity Assessments</p>	<p style="text-align: center;"><b>Closure</b></p>
	<p>Create a project rubric to grade by. Teachers can assign point values for quality of research, references, engagement, etc. that are appropriate for their class and the amount of time given. Be sure it is available for students to reference as they work.</p>
<p style="text-align: center;"><b>Culturally Inclusive/Responsive Components</b></p>	
<p>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.</p>	
<p style="text-align: center;"><b>Educator Resources</b></p>	