RADIO EXPLORERS

Radio Silence

FACILITATOR GUIDE

Learning objectives

1. Radio waves transfer energy that can be reflected or absorbed, or pass through materials.
2. Radio waves are invisible and all around us.
3. Different devices use different radio frequencies.

Materials

Not all the materials listed below are necessary to run this activity. The text in bold lists the minimum number of materials needed to run the activity.

- **At least two devices that use radio waves.** Suggestions include: a portable radio, a Bluetooth speaker (connected to a tablet, laptop, or smartphone), or two walkie-talkies. Small portable radios can be found at most big-box and hardware stores or online. Consider a radio that does not require batteries.
- **At least two conductive materials.** Suggestions include: an empty metal paint can, fine copper wire mesh, tinfoil, a commercial Faraday bag, additional metal mesh sheets made from different metals (note that sheets with larger mesh sizes are very hard to manipulate and have sharp edges), or a metal toolbox. Empty paint cans and fine wire mesh can be found at most hardware stores or online. Faraday bags can be found online—try to choose one that will be large enough to fit your chosen devices.
- **At least two nonconductive materials.** Suggestions include: a large plastic storage container, plastic paint can, paper bag, cardboard box, acrylic box, towels, cloth, or gallon-size plastic storage bags.
- Tape and scissors, depending on your material choices.
- Activity guide and information sheets.

Safety

Take care with the edges of any metal wire mesh, as they can cut and poke hands. Make sure to examine all metal wire mesh as you set up the activity, and tape or snip off the sharp edges (see below).

Training Videos

Facilitators should review the training video for this activity for facilitation guidance and examples of specific materials. The *Making Waves with Radio* content training video will provide additional background content to help in the facilitation of this activity.

Activity Training Video: https://vimeo.com/776687111

***Making Waves with Radio* Content Training Video:** https://vimeo.com/776685410

***Making Waves with Radio* Content Training Video (Spanish):** https://vimeo.com/776686149

Advance Preparation

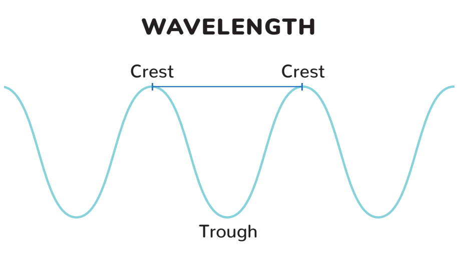
Before you begin

Tape the edges of the copper wire mesh using conductive tape. This will help to cover any jagged wire. Copper tape can be found at a local hardware store or online.

Tune the radio to a station and tape down the dials so they cannot be changed. If the tuning dial is not taped, it may accidentally tune to static while being handled and confuse the learner during the experiment.

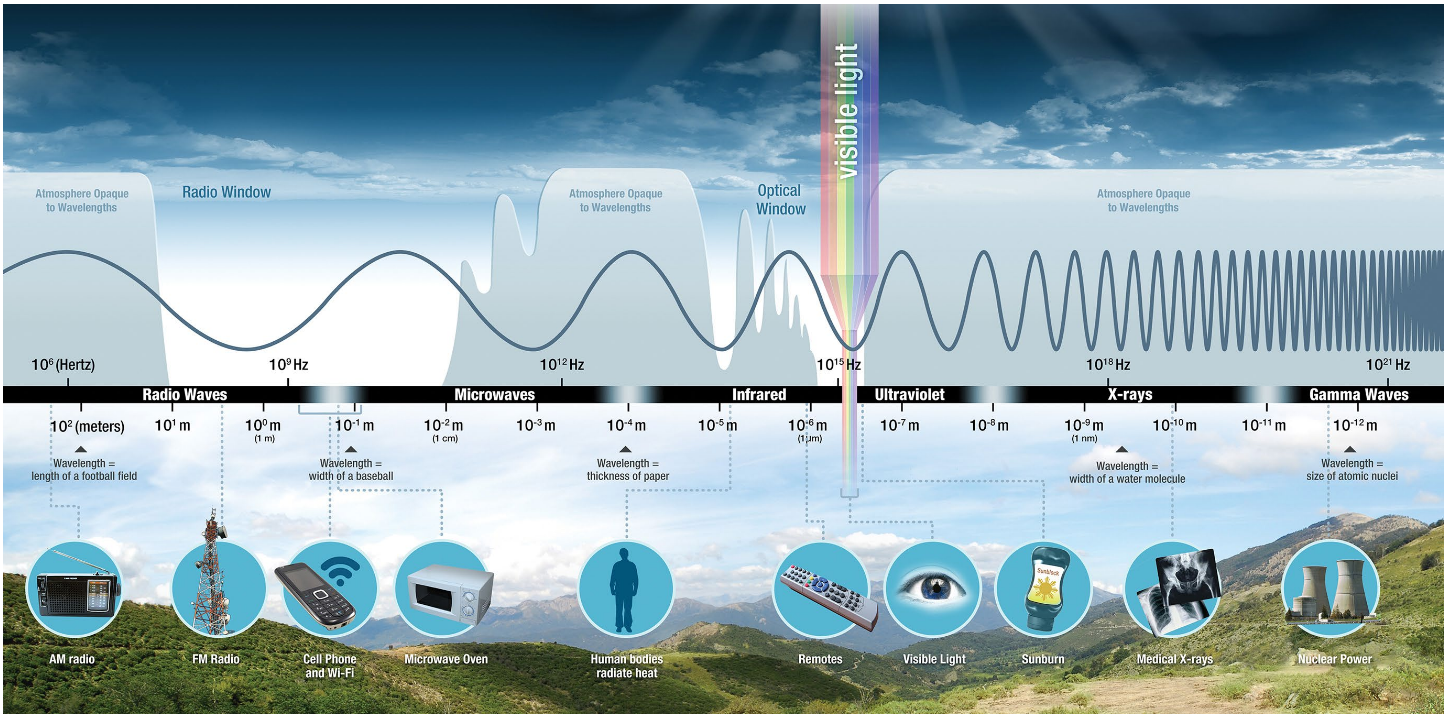
Content Background

Radio waves were first identified as a phenomenon in the 1880s, and radio transmitters were commercially available by 1900. Today, many modern communication devices use radio waves, including televisions, cell phones, walkie-talkies, Wi-Fi, Bluetooth, and satellites.



Simplified image of a wave and its parts.

Radio waves are one type of electromagnetic wave in the electromagnetic spectrum shown below. Electromagnetic waves, like ocean waves, transmit energy and have **crests** and **troughs**. But unlike ocean waves, radio waves and other electromagnetic waves don't require water. In fact, electromagnetic waves don't require any medium to travel. They can travel through air, solid objects, and even space! The distance from **crest** to **crest** of a radio wave is called its **wavelength**. Electromagnetic waves of longer wavelengths, like radio waves, carry less energy than those of shorter wavelengths, like X-rays or gamma waves. Radio waves can have wavelengths greater than 100m (shown in the figure below as 10^{2}m) or as small as 1 mm (10^{-3}m).

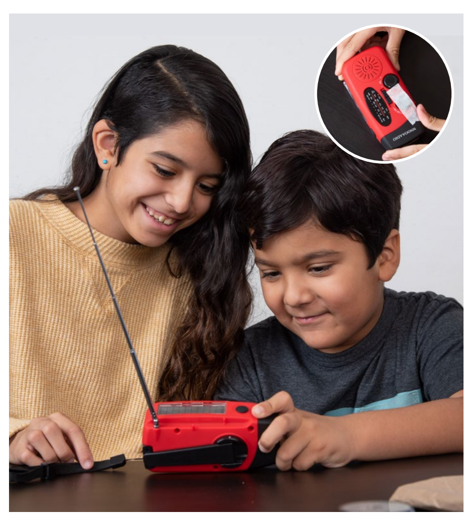


NASA

Electromagnetic waves travel at the speed of light. The number of **crests** that pass a given point in one second is described as the **frequency** of the wave. Electromagnetic waves with higher frequencies—and therefore shorter wavelengths—carry more energy.

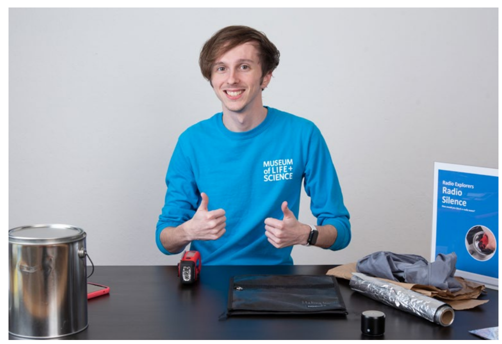
Notes to the Presenter

- A material's ability to block or interfere with radio waves will depend on its thickness and composition. Facilitators will need to strike a balance with participants in creating a Faraday cage that interferes with radio waves versus one that simply muffles the sound produced by the various testing devices. Try increasing the volume or comparing Faraday cages using similar thicknesses built from two different materials.
- Radio stations can be hard to find for some younger learners. Assist them in slowly turning the tuning dial until you hear music or speaking, or present them with a preset station that comes in well where you are located. Once the station is set, tape over the tuner and volume dials to prevent the station and volume from being changed during the experiment. Keep in mind that leaning close to the radio in a container may transmit a signal unintentionally. This in itself can be used as a learning opportunity.



- Devices like cell phones and Bluetooth speakers use different frequencies that are harder to block than frequencies used in FM and AM radios. Try doubling up materials to block the signal. Make sure to use a variety of materials that can and cannot block radio signals. If using metal mesh sheets, non-copper wire mesh can be very hard to manipulate, especially as the mesh size increases.
- Many participants will discover touching the radio antenna changes the signal reception. This can become an opportunity to ask participants what they think is happening to radio waves in the air that hit our bodies. What happens to the energy of these radio waves when we touch an antenna?

Museum floor facilitation (up to 15–20 minutes)



- Lay out two devices that use radio waves, along with conductive and nonconductive materials, on a table, cart, or working surface.
- Invite participants to engage with opening questions: Would you like to try this? Have you ever used a radio? Ask the participants to elaborate on their experiences.
- Engage in a conversation that encourages participants to think about how radio waves reach the radio. What about the Bluetooth speaker? Walkie-talkies? Cell phones?
- Encourage participants to explore the materials and form hypotheses about which materials might block radio waves from the devices. Be sure to test it out!
- Use exploration questions: What would happen if you cover only half of the radio? Are these materials the same or different?
- When the signal is blocked by a material, inspire reflection by asking: Why do you think that happened? What would happen if you change the orientation of the radio? What about if you raised the antenna? Lowered it? This is a good time to bring up real-world applications of the experiment: Does the participant ever lose cell phone service? What about their car radio in a tunnel?

- After the participants have blocked waves to the radio, try another device. The radio waves of higher frequencies used by walkie-talkies and Bluetooth devices are harder to block. Encourage the participants to combine materials.
- When the participants are done with the activity, thank them for their participation and encourage them to think of the role radio waves have in their life. Reset the materials before the next participants.

Tips for facilitating with younger participants

- Very young children may not grasp the concept of radio waves, but will still enjoy experimenting with material and sound. Encourage children to experiment with the portable radio sound dial, move the portable radio antenna, or manipulate the materials.
- Presenting materials that are easier to manipulate (e.g., a metal or plastic paint can, Tupperware, etc.) can help the experiment run smoothly. Plastic bags and wire mesh can be difficult for early learners to navigate.
- Guide the learner by asking questions like: What does the radio sound like? How are these materials different? What happens when you put the radio in [the paint can, the plastic tub, etc.]?

Common Questions

Are radio waves passing through my body?

When the learner touches the radio inside a container that otherwise blocks radio waves and the signal returns, they may realize that the radio waves are traveling through their bodies. Many learners find this unsettling. Radio waves are a type of nonionizing radiation, just like visible light. This means radio waves do not directly damage our cells the way other types of radiation do, like gamma radiation. In addition to human-made sources, radio waves are produced by outer space, the sun, and even the Earth itself.

Why is it harder to block radio waves to the Bluetooth speaker or walkie-talkie than the portable radio?

These devices use different frequencies. The Bluetooth speaker or walkie-talkies use higher frequencies than the portable radio. Higher frequency waves have shorter wavelengths. Generally, a radio signal can be transmitted through any hole larger than its wavelength. So the shorter radio waves of the higher frequency signals used by Bluetooth and walkie-talkies can be transmitted through much smaller holes or gaps in your Faraday cage than the longer radio waves of the lower frequency signals used by the portable radio.

Consider why you can hear an FM radio station on a car radio longer than an AM station when driving into a tunnel. A single radio wave from an FM station is about the length of a car—a few meters long. But an AM station transmits radio waves that can each be hundreds of meters long! These longer AM radio waves are absorbed or blocked as they try to enter the much smaller tunnel opening, but the shorter FM radio waves sneak in and bounce inside the tunnel.

If radio waves are all around us, why can't I sense them?

Our eyes have evolved to be precisely tuned to the properties of visible light waves. As the longest-wavelength electromagnetic waves, radio waves have much longer wavelengths than the waves that make up visible light.

Radio and television, cell phones, GPS, radar, Wi-Fi, and Bluetooth all use radio waves. It takes a lot of radio waves to make these devices work! That means radio waves are all around us, all the time. Though we can't see radio waves, we can observe them all around us in our functioning technology. Every time a text arrives, a car radio turns on, or you connect to the internet without any wires, that demonstrates that radio waves can be everywhere.

Developed with funding from the National Science Foundation under Award Number 2053160.

Photos and illustrations by Emily Maletz Graphic Design for the NISE Network unless noted.

This material is based on work supported by the National Science Foundation under award number #2053160. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the view of the National Science Foundation.