

Unit 3 Lab 2

Radio Waves from Space



Teacher Version

Unit 3 Lab 2:

Radio Waves from Space

Objective: In this lab, students will measure and compare the peak intensity of 21 cm radio waves emitted from the gas and dust between five different objects.

Teacher Notes



PARIPod 3.2 is still in development.

Background Knowledge

When we discuss electromagnetic waves we usually think of visible light, but visible light actually makes up only a small fraction of the electromagnetic spectrum. The electromagnetic spectrum is the total range of frequency or wavelengths of electromagnetic waves. The spectrum's range extends from the long wavelengths of radio waves to the short wavelengths of gamma waves. Below is a diagram of the electromagnetic spectrum (**Figure 1**).

Electromagnetic waves are similar in many ways to mechanical waves, therefore many of the terms and mathematical equations used for mechanical waves can be used in the study of electromagnetic waves.

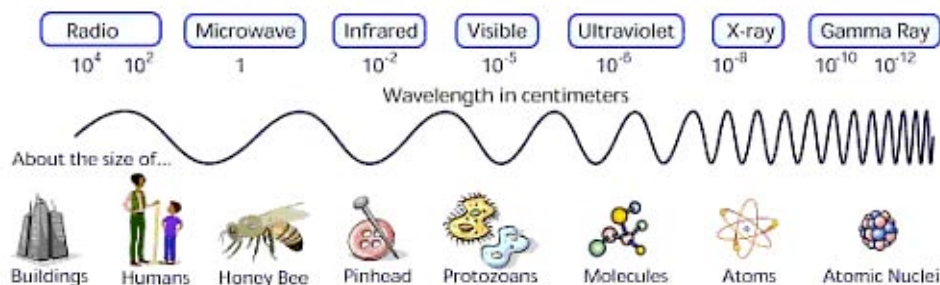


Figure 1. The Electromagnetic Spectrum.

For simplicity we can think of an electromagnetic wave as energy that is moving from place to place and travels in the form of a transverse wave. Illustrated below is the relationship of wavelength and frequency of a transverse wave (**Figure 2**).

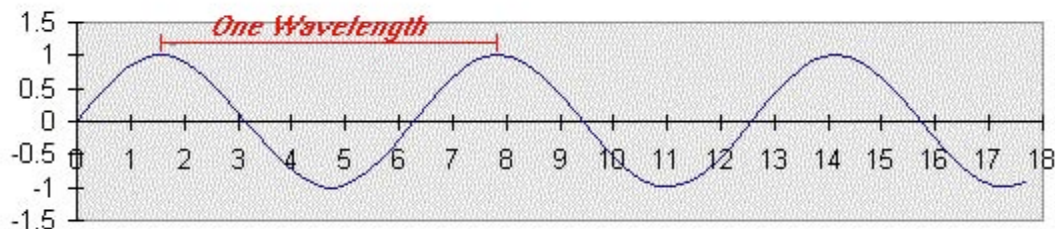


Figure 2. Definition of wavelength.

Wavelength: The distance from one crest of a wave to the next and is denoted by the Greek letter lambda λ . Example in **Figure 2** the wavelength is about 6.5 units.

Frequency: The number of crests, troughs, or any other point on the wave that passes a given point in a unit time interval. (f)

Amplitude: The maximum displacement of the wave from an equilibrium position. In the image above, the equilibrium position is 0 so the amplitude is 1. There is positive and negative displacement for each wavelength. The displacement is proportional to the amount of energy. Therefore, the greater the displacement, the larger the amount of energy associated with the wave.

Wavelength and frequency are inversely proportional, meaning that if the frequency goes up, the wavelength goes down. The same is true vice versa. As well, all forms of electromagnetic radiation travel at the same high velocity, the speed of light (c). The current accepted value for the speed of light is 2.997992458×10^8 meters per second (m/s). For this lab the rounded value of 3.00×10^8 m/s is acceptable.

The relationship between frequency, wavelength, and the speed of electromagnetic radiation is given by:

$$c = f \cdot \lambda$$

Pre-Lab Questions:

1. Radio waves travel at the speed of light. A source emits radio waves with a wavelength of 6 cm. What is the frequency of the radio emission?

$$\begin{aligned} \underline{3.0 \times 10^8 \text{ m/s} = f(.06\text{m})} \\ \underline{5.0 \times 10^9 \text{ m/s} = f} \end{aligned}$$

2. Radio waves travel at the speed of light. The Galileo spacecraft orbiting Jupiter sends a signal 670 million km to earth. How long does the signal take to reach earth? (velocity = distance/time)

$$\begin{aligned} \underline{3.0 \times 10^8 \text{ m/s} = 6.7 \times 10^{11} \text{ m/time}} \\ \underline{2.23 \times 10^3 \text{ s} = \text{time}} \\ \underline{37.22 \text{ minutes}} \end{aligned}$$

3. Compare the wavelength of a radio wave with a frequency of 1.42 GHz to the wavelength of a visible light wave with a frequency of 6×10^{14} Hz.

$$\underline{a) 3.0 \times 10^8 \text{ m/s} = 1.42 \text{ GHz} * \lambda = 2.11 \times 10^{-1} \text{ m} = 0.211 \text{ m}}$$

$$\underline{b) 3.0 \times 10^8 \text{ m/s} = 6 \times 10^{14} * \lambda = 5.0 \times 10^{-7} \text{ m}}$$

The wavelength of the visible light wave is much shorter than the radio wave.

4. Why can your radio pick up radio waves through walls, yet you cannot see through walls?

The longer wavelengths of the radio waves can travel through solid objects. The shorter wavelength of visible or optical waves, however, cannot pass through solid objects.

Procedures

1. Students should answer the pre-lab questions above before beginning the lab.
2. Instruct students to log into the Smiley Observation Control Room. For information on how to use Smiley, please refer to PARIPod Unit 2 Smiley basics
3. With **Map** selected, click on the Sun as your source object. Click on **GO**.
4. Once the status bar reads “Mover stopped”, use **Hand Paddle** to position Smiley as close as you can to the source.
5. In **Continuum** mode choose the **Base Frequency** to be 1.42 GHz and your **IF GAIN** to be 10.
6. Now click on **Begin Scan**. Once the scan is complete and it starts to plot again, click on **Stop Scan**. To find the maximum intensity click on **Save Scan** and save your scan. Then click on **Open Data File** and click on **List** on the file you just saved. Look through the data points and find your maximum intensity. Record the maximum intensity in the data table below.
7. **Clear** the scan. While on the same object choose the **Base Frequency** to be 4.8 GHz.
8. Click on **Begin Scan** and follow the same procedure as you did in # 6 and 7. Record the maximum intensity in the data table.
9. Next, calculate the wavelength using the equation $c = f * \lambda$ for each frequency and record it in the data table below.
10. Now take the ratio of the maximum intensity at 1.42 GHz to the maximum intensity at 4.8 GHz (divide the 1.42 GHz maximum signal by the 4.8 GHz maximum signal) and record it in the data table below.
11. Repeat steps 3-11 for two more objects above the horizon.

Data Collection

Ratio of Maximum Object Frequency Wavelength Maximum Signal Intensities

Object		Intensities
	1.42 GHZ	
Sun:		
	4.8 GHZ	
	1.42 GHZ	
Object 2:		
	4.8 GHZ	
	1.42 GHZ	
Object 3:		
	4.8 GHZ	

Analysis and Discussion

1. What can you observe from the ratios calculated in your results?

The ratios are approximately 1.0. However, the 1.42 GHz signal is slightly stronger than the 4.8 GHz signal.

2. Using your data, explain how wavelength and frequency are inversely proportional.

The wavelength for 1.42 GHz is 2.11×10^1 m while the wavelength for 4.8 GHz is 0.625×10^1 m. Therefore, the lower the frequency the longer the wavelength, and vice versa.

3. The sun is much more intense in the visible part of the electromagnetic spectrum than in the radio. This suggests that higher frequencies are more intense. Is this what you observed?

No, the 1.42 GHz signal is more intense.