How Waves Helped win the war: RADAR and SONAR in WWII

Objectives:

1. 1. Students will learn some basic historical facts about the role of radar in the Battle of Britain and sonar in WWII anti-submarine warfare.
2. 2. Students will learn similarities and differences between sonar and radar.

Directions:

1. 1. Have students read Introduction and Radar and Sonar Compared, followed by completion of the table and problems.

Assessment:

1. Components for assessment include completion of table, solutions to problems and answers to any historical questions the teacher may add.

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So What is This About?

Introduction:

Radar (**Ra**dio **D**etection **a**nd **R**anging); **Sonar** (**So**und **N**avigation **a**nd **R**anging)

Two similar but different technological advances that figured prominently in the Allied victory in World War II were radar and sonar, both techniques for detecting the location and speed of enemy aircraft or submarines.

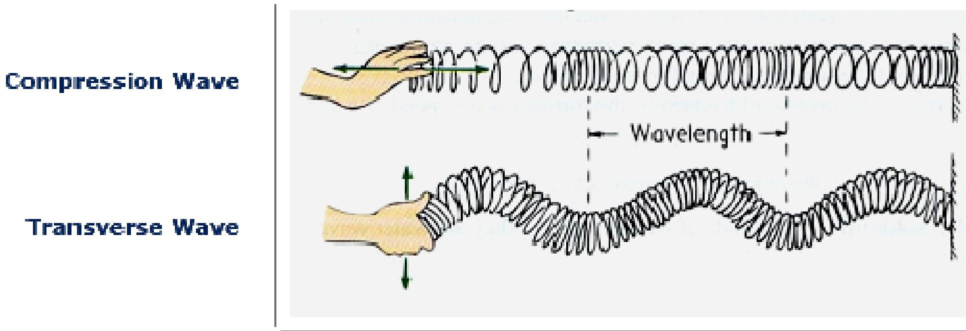
During World War II, radar played a critical role in the British victory in the Battle of Britain, an aerial battle fought largely between August 1940 and the end of that year. In August of 1940 Britain stood alone in the war in Europe, the German army having defeated Britain's Polish allies in September of 1939, and the French in June of 1940. By August, Hitler had given up attempts to persuade the British to sign a peace treaty favorable to Germany. He started planning an invasion of Great Britain, but first he had to deal with the British air forces. Hitler had reason to be optimistic. The British had only 800 aircraft to try to hold back the onslaught of over 3,000 German planes. The British victory in this battle was largely due to a series of radar stations that had been built along the southern and eastern coasts of Britain in 1939. These radar stations enabled the British to determine the direction, altitude, and speed on oncoming German aircraft while they were still 50 to 60 miles away, and thus concentrate their limited fighter forces against them.

The use of sonar was largely directed against German submarines. Following their failure in the Battle of Britain, the Germans began to use submarine warfare in an attempt to cut off British shipping, upon which Britain depended for vital war materials and food. The use of sonar allowed the powerful British surface fleet to detect the direction and depth of these submarines and destroy many of them.

Radar and Sonar Compared

What makes these two technologies similar is that they both locate enemy ships or planes at a distance by sending out invisible waves that strike the ship or plane, and bounce off and return to a wave detector. The returning waves provide information as to the direction of the enemy craft, as well as their velocity. How are these waves similar? Radar waves and sonar waves exhibit the properties of all waves, including wavelength, frequency, velocity, reflection, and changes in wavelength resulting from the motion of the wave source relative to a stationary detector (the Doppler Effect).

Sonar makes use of sound waves to detect distant objects. (Radar uses radio waves which are more like light than sound.) The use of sonar was "invented" by bats and dolphins long before it was employed by humans. Bats locate flying insects at night by producing sound waves with such a high frequency that they cannot be heard by the human ear. These waves strike the insect and are reflected to the bat's ear, allowing the bat to detect the location of the insect. Biologists call this **echolocation.** Sound waves, which are called **compression waves,** are produced by vibrating objects. When a vibrating object moves toward us, the air molecules are pushed closer together. When the object vibrates away from us, the reverse happens. You can simulate this in one dimension with a long spring, like a slinky toy. Stretch the spring, and push a few coils of the spring closer together. When the compressed coils are released, a wave of compression will move away from its original location. When this compression wave strikes the fixed other end of the spring, a reflected wave can be seen. Sound waves travel longer and faster in water that they do in air. The velocity of sound in water is about 1.6 kilometers/second.



Radar makes use of radio waves to detect distant objects. As already mentioned, radio waves are more like light than sound. Why? First, because like light (which also travels in waves), they travel at the same velocity as light; 300,000 kilometers/second or 300,000,000 meters/second. This is enormously faster than sound waves travel.

Second, like light, and unlike sound, radio waves are **transverse waves,** not compression waves. You can simulate this in two dimensions with a long spring, like a slinky toy. Stretch the spring and then move one end of the spring from side to side at right angles to the length of the spring. Waves similar to those on the surface of water can be seen to form. Third, neither radio waves nor light waves travel as far in water as sound waves.

Radio waves are different from light waves in at least two ways. First, unlike light, we cannot see radio waves because the wavelength of these waves is too long for the human eye to detect. See figure 1 below:

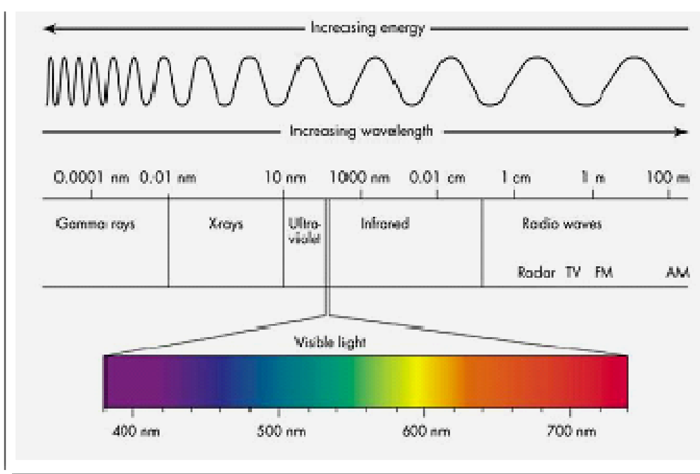


Figure 1: Diagram showing the concept of wavelength and comparing radio waves to the visible spectrum in this regard.

Second, radio waves are not scattered as much as light waves by gas and dust, and can penetrate clouds.

Lab Report

Complete the table below by circling the correct answers in column I and column II.

	I. Radio Waves	**II. Sound Waves**
Basis for (circle one)	radar / sonar	radar / sonar
Type of wave (circle one)	compression / transverse	compression / transverse
Travels best in (circle one)	air / water	air / water
Best in detecting (circle one)	aircraft / submarines	aircraft / submarines

Complete the following computations to solve for D (Distance). Show all your work for full credit. Circle your answer when done.

1. What is the range (distance to) of an aircraft for which a radar pulse from a land radar station requires half of a millisecond (0.00050 seconds) to travel to the aircraft, be reflected and return? Remember, the velocity of radio waves is 300,000km/second. Use the formula: Round-trip distance = velocity x time

2. A destroyer on the ocean surface detects the reflection of a sonar "ping" (sound pulse) off a submarine a tenth of a second (0.10 seconds) after it was produced by the sonar device on the destroyer. What is the depth of the submarine? Remember, the velocity of sound in water is about 1.6km/second. Use the formula: Round-trip distance = velocity x time