Making Waves

Sonar, Radar, and Communication aboard the USS Hornet

From the USS Hornet Museum Education Department

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(AD: May 2018)

About This Document

The USS Hornet relied on radar and sonar for both navigation and communication. Both were vital for tracking both friendly and enemy ships and submarines, as well as aircraft within the vicinity of the Hornet. This program gives students the opportunity to investigate the various waves and their properties and connect them to the ship's technology. This program is designed for 3rd through 5th grade.

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Goals

In this program, students will:

- Observe various wave patterns
- Work collaboratively to create those waves
- Practice the scientific method by making hypotheses and observations

Objectives

In this program, students will:

- Understand the difference between electromagnetic and mechanical waves
- Understand how the USS Hornet used sonar and radar to navigate and communicate

Big Questions…and Answers

How are radio waves produced?

Radio waves are electromagnetic waves and therefore to not require a medium like air or water to travel. They can travel much farther as a result.

How is sonar produced?

Sonar waves are mechanical and require a medium like air or water through which to travel; otherwise they diminish over the distance traveled.

Program Outline

<u>Approximate Program Timeline-</u>

40 minutes total:

-Overview of sonar and radar on the Hornet- 20-25 minutes

-Demos- 10-15 minutes

-Debrief- 5-10 minutes

Materials Needed:

Slinky

Rope (6-8 ft long)

Small piece of brightly colored yarn (or visible tape)

Procedure:

Transverse Waves

Wave Properties

(Slinky Option)

Have students get into groups of 3: one student holding one end of the Slinky is the "ship", while the student at the other end is the "plane"; the other student is the "observer." (Students may switch off during the activity.)

First, tie the piece of yarn to any point around the middle of the Slinky. (Position is not critical; it is only serving as a visual marker.)

1. Students sit on the floor facing each other, far enough apart so that the Slinky is stretched out and straight).
2. The "ship" student moves one end of the Slinky side to side at a constant rate to create a *transverse* wave. Note the wavelength of the wave you create.
3. Repeat this several times while making the following observations:
    a. *In which direction does the wave move? (Along the length of the Slinky)*
    b. *In which direction does the Slinky move (look at the yarn/tape marker)? (Side to side, or perpendicular to the direction of the wave along the Slinky)*
    c. *What provides the energy carried by the wave? (The arm motion shaking the end)*
4. Now, students create a bigger wave.

   a. *How did you make it bigger? (Bigger/stronger arm motion)*

   b. *Do you think this took more or less energy? (More energy)*

5. Now, students create a higher-frequency wave.

   a. *How did you do this? (Move arm faster)*

   b. *Do you think this took more or less energy? (More energy)*

What can you conclude about the relationship between the amplitude and frequency of a wave and the energy it carries? (Higher amplitude and frequency = higher energy)

(Rope Option)

Have students get into groups of 3: one student holding each end of the rope (or tie one end of the rope to a chair), with the other as the "observer." (Students may switch off during the activity.) The rope should be almost straight, but not taut.

First, tie the piece of yarn to any point around the middle of the rope. (Position is not critical; it is only serving as a visual marker.)

1. The "plane" student holds one end of the rope tight and close to keep it as steady as possible.

2. The opposite student moves the other end of the rope quickly up and down to create a wave.

3. Repeat this several times while making the following observations:

   a. *In which direction does the wave move? (Along the length of the rope)*

   b. *In which direction does the rope move (look at the piece of yarn)? (Up and down, or perpendicular to the direction of the wave along the rope)*

   c. *What provides the energy carried by the wave? (The arm motion shaking the end)*

4. Now, students create a bigger wave.

   a. *How did you make it bigger? (Bigger/stronger arm motion)*

   b. *Do you think this took more or less energy? (More energy)*

5. Now, students create a higher-frequency wave.

   a. *How did you do this? (Move arm faster)*

   b. *Do you think this took more or less energy? (More energy)*

What can you conclude about the relationship between the amplitude, frequency, and wavelength of a transverse wave and the energy it carries? (Higher amplitude and frequency, shorter wavelength = higher energy)

Hornet Application to Radar

Radar uses radio waves through the air to track aircraft and other objects. A plane is a solid object, so the waves will go through the air and then “bounce” off of the plane. The time it takes for the reflected wave to return can be used to calculate the distance of the object.

1. One student holding the rope/Slinky will be the “ship” and the other will be the “plane”. The “ship” student creates a single–pulse transverse wave that travels the length of the rope/Slinky, where it is reflected off the “plane” student. Repeat this several times while making the following observations about the reflected wave:

   a. *What happens at the fixed end? (Reflects back along the rope/Slinky)*

   b. *Is the reflected wave the same or different as the original one? (Same frequency, slightly less* *amplitude; returns on the other side of the spring ("inverted" or "phase shift")*

2. Now, the "plane" student changes position by moving towards and away from the "ship." (between waves; not continuous motion). Repeat this several times while making the following observations about the reflected wave:

    a. *When the "plane" is closer, what happens to the time it takes for the wave to return? (Shorter time)*

    b. *When the "plane" is farther away, what happens to the time it takes for the wave to return? (Longer time)*

3. (Optional, perhaps for 5th graders. This also might be a little tricky, but we'll test it out.) Now, when the "ship" sends the pulses, the "plane" student moves towards and away from the "ship." Repeat this several times while making the following observations about the reflected wave:

    a. *As the "plane" moves closer, what happens to the reflected wave? (Frequency increases)*

    b. *As the "plane" moves further away, what happens to the reflected wave? (Frequency decreases)*

How does this help to detect objects? (By knowing the speed of the wave, and measuring the time it takes the reflected wave to return, we can calculate the distance to the object. If the frequency of the reflected wave has shifted from the original- Doppler Effect-, we can determine the motion of the object.)

<u>Longitudinal Waves</u>

1. Students sit on the floor facing each other, far enough apart so that the Slinky is stretched out and straight). This time, one student is the "ship" and the other student is the "submarine."

2. "Bunch up" one end of the Slinky and then release it to create a *longitudinal* wave; do this in a repeated pattern.

3. Repeat this several times while making the following observations:

    a. *In which direction does the wave move? (Along the length of the Slinky)*

    b. *In which direction does the Slinky move (look at the yarn/tape marker)? (in line with the Slinky, or parallel to the direction of the wave along the Slinky)*

    c. *What provides the energy carried by the wave? (Releasing the compressed spring section)*

4. Now, students create a bigger wave.

    a. *How did you make it bigger? (More coils bunched together)*

    b. *Do you think this took more or less energy? (More energy)*

5. Now, students create a higher-frequency wave.

    a. *How did you do this? (Compress and release coils at a faster rate)*

    b. *Do you think this took more or less energy? (More energy)*

What can you conclude about the relationship between the amplitude and frequency of a longitudinal wave and the energy it carries? (Higher amplitude and frequency = higher energy)

<u>*Hornet* Application to Sonar</u>

1. One student holding the rope/Slinky will be the "ship" and the other will be the "submarine." The "ship" student creates a single–pulse longitudinal wave that travels the length of the Slinky, where it is reflected off the "submarine" student. Repeat this several times while making the following observations about the reflected wave:

c. *What happens at the fixed end? (Reflects back along the rope/Slinky)*

d. *Is the reflected wave the same or different as the original one? (Same frequency, slightly less amplitude.)*

2. Now, the "sub" student changes position by moving towards and away from the "ship." (between waves; not continuous motion). Repeat this several times while making the following observations about the reflected wave:

   a. *When the "sub" is closer, what happens to the time it takes for the wave to return? (Shorter time)*

   b. *When the "sub" is farther away, what happens to the time it takes for the wave to return? (Longer time)*

3. ((Optional, perhaps for 5th graders. This might be a little tricky, but we'll test it out.) Now, when the "ship" sends a series of pulses, the "sub" student moves towards and away from the "ship." Repeat this several times while making the following observations about the reflected wave:

   a. *As the "sub" moves closer, what happens to the reflected wave? (Frequency increases)*

   b. *As the "sub" moves further away, what happens to the reflected wave? (Frequency decreases)*

What do you think happens when a sound wave hits an object? (The wave "bounces" off of it and returns back to the source)

How does this help to detect objects? (By knowing the speed of the wave, and measuring the time it takes the reflected wave to return, we can calculate the distance to the object. If the frequency of the reflected wave has shifted from the original- Doppler Effect-, we can determine the motion of the object.)

Background Reference Material

Island

Navigation was where the ship's Navigator and his Quartermaster plotted the course of the ship and stored charts and navigation tools. The Navigation Bridge includes the Pilot House and Chart Room, the Flag Bridge, and Weather Room. Pri-Fly is also located in the Island, but was mainly concerned with activity on the flight deck rather than navigation.

When navigating, you need to know 3 things:

- Where are you?
- Where do you want to go?
- What is the best way to get there?

Although the shortest distance between two points is always a straight line, this may not be the best route due to weather conditions, geography, or other obstacles (like an enemy fleet!)

Other than GPS (which we use now), there are three ways to determine position:

- Piloting
- LORAN
- Celestial navigation

When unable to use any of these three ways, a properly trained Quartermaster of the Watch would use Dead Reckoning to determine the position of the ship.

Chart Room

The Dead Reckoning Tracer (DRT) is an analog computer (made of gears rather than computer chips) that the navigators would have used to track their position. The DRT requires the ship's longitude and latitude, and then follows its changing position through speed and direction. It did not take into account tides and winds.

The LORAN (Long Range Navigation) system was another way to track positions. The ship has a receiver unit that can sense low frequency radio signals transmitted by fixed land-based beacons, and triangulates the ship's position based on the signals it's receiving. Both this and the DRT have been outdated by modern GPS.

Pilot House

The Surface Scanning Radar was used in Navigation when piloting to track a ship's position in relation to objects in the surrounding environment. It could sense other ships but could also track the ship's distance from land, bridges, piers, and anything else that touched the surface of the water.

How did the Hornet *use waves to keep track of her position?*

Both LORAN and surface scanning radar could give a position, but there are some important differences.

LORAN determined location (i.e., map coordinates) based on a "fix" established by radio waves transmitted from points on land.

SSR gave the ship's position relative to other objects that touched the surface of the water by transmitting (this time from the ship) radio waves that bounced off of the objects.

Both systems use wave patterns, i.e., speed of a radio wave and the time it takes to travel back and forth to determine distances.

Combat Information Center

CIC was a classified area and was only accessible by authorized personnel stationed here or those who gained permission to enter by the Commanding Officer. Personnel working within such areas were highly qualified and worked 12 hour shifts "12 0n 12 off ". Approximately 40 people worked within five compartments and were all seated of swivel stools (removed).

All plotted course and information was marked on the status boards surrounding the CIC and associated compartments. Information was marked by writing backwards with grease pencil so as not to block the vision of this constantly updated information.

The master air display status board ("spider web") tracked all aircraft operating in the vicinity of *Hornet* and her task group. The operational tracking radius of this display board is 500 miles, the equivalent range of the air search radar.

The combined Surface/Air display status board tracked all ships and aircraft operating in the vicinity of the Ship and her Anti-Submarine Warfare (ASW) task group.

Status board information was also most useful during a power loss. When power was restored the crew still had the last plotted course and information to reacquire the target.

All radar scopes read the same radar information but individually were used to track different information such as fixed wing control, rotary winged control, ASW control, and IFF (Friend or Foe).

Sound-powered phones were a major part of the communications system of the ship (and are still in use today. These phones are powered by the vibrations of speech against a plate in the mouthpiece and do not require any electrical power.

Another important communications component was the system of voice tubes that pass between key compartments.

The CIC compartment ran in blue lights when the ship was underway" Operational"; white lights were only on when the ship was in port cold or for cleaning maintenance or modifications in the yard.

How did the Hornet *use sonar to track submarines and radar to track airplanes?*

SONAR was used to track submarines because sound waves travel better (and farther) in the water.

Radar was used to track airplanes because radio waves travel better (and farther) in air.

However, in both systems, waves are sent out from the ship ("transmitted"). If the wave hits something, it bounces off the object and a "reflected" wave returns to the ship.

The pattern of the returning wave can tell the distance and speed of an object:

The speed of the returning wave and the time it takes to return are used to calculate the distance.

The frequency of the returning wave tells if the object is moving.

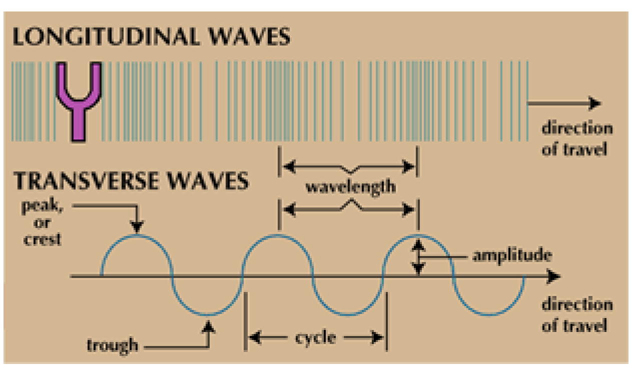
If it is higher than the transmitted wave…object moving towards the ship.

If it is lower…object moving away from the ship.

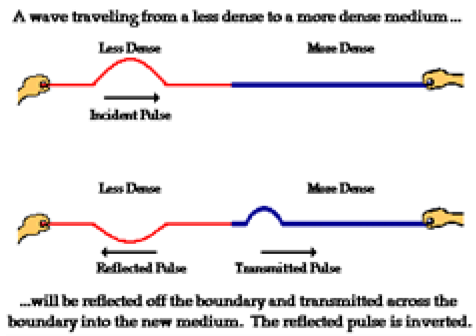
Next Generation Science Standards

Grade Level	Standards
3-5	*Engineering Design:* 3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. 3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
4	*Waves and Their Applications in Technologies for information Transfer:* 4-PS4-1. Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move. 4-PS4-3. Generate and compare multiple solutions that use patterns to transfer information.

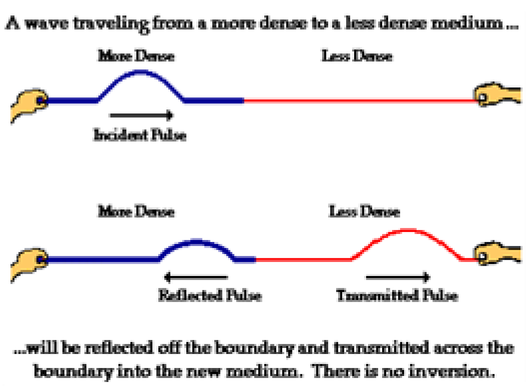
Appendix:



(http://kids.britannica.com/comptons/art-53868/Sound-waves-are-longitudinal-waves)



(http://www.physicsclassroom.com/class/waves/Lesson-3/Boundary-Behavior)



(http://www.physicsclassroom.com/class/waves/Lesson-3/Boundary-Behavior)

Links and Credits

Docent Scott Zirger has created a wiki for the ship containing a wealth of information:
https://en.wikipedia.org/wiki/User:Szirger/Books/USS_Hornet_Reference_Material

This program was created in conjunction with a grant from the Office for Naval Research and expands upon ideas found in the following lesson:
http://usnavymuseum.org/Education_LP0013.asp