OCEAN EXPLORATION & RESEARCH

Section 2: Telepresence for Volume 2: How Do We Explore?

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site: http://oceanexplorer.noaa.gov/okeanos/welcome.html

Okeanos Explorer's prominent VSAT (Very small aperture terminal) dome enables satellite communications between explorers ashore and at sea and provides multiple high-definition video streams for widespread dissemination. Image credit: NOAA.

Please Pass the Remote

Focus
Wireless communications for ocean exploration

Grade Level
7-8 (Physical Science)

Focus Question
How does wireless communications technology contribute to human communication, and how is this technology used aboard the NOAA Ship *Okeanos Explorer* to investigate unknown areas in Earth's ocean?

Learning Objectives
- Students will identify and discuss at least five ways in which they use wireless technology in their daily lives.
- Students will discuss the importance of communication to science and describe some of the factors that contribute to the complexity of human communication.
- Students will discuss factors that influence the effectiveness of human communication.
- Students will identify and explain the major components of a wireless communications station, and how these are used to implement telepresence aboard the NOAA Ship *Okeanos Explorer*.

Materials
- Copies of *Wireless Communications Worksheet*, and (optionally) *Hands-On Activity Guide Wireless Communications: Build the Simplest Radio*; one copy for each student or student group
- (Optional) Materials for *Make the Simplest Radio* activity:
  - 150 ft - #24 insulated wire (twin-lead speaker wire may be less expensive than regular hookup wire)
  - 1 - 1N4001 diode (*e.g.*, Radio Shack 276-1101)
  - 1 - 100-pf disc capacitor (*e.g.*, Radio Shack 272-0123)
  - 1 - resistor, 47 K-ohm, 1/2- or 1/4-watt
  - 2 - Alligator clips (*e.g.*, Radio Shack 270-380)
  - 1 - High impedance ceramic earphone (or the amplified speaker used in the Light Beam Modulation activity included with the *A Day in the Life of an Ocean Explorer* lesson)
  - 5 - Machine screws, 6-32 x 1/2-inch
  - 10 - 6-32 nuts
  - 5 - Solder lugs, #6 hole
  - 1 - Empty round oatmeal box

3 ft - Masking tape
1 ft - Solder

- Tools for *Make the Simplest Radio* activity:
  1 - Pair small wire cutters
  1 - Awl or ice pick
  1 - Pair needle nose pliers
  1 - Soldering iron; approximately 60 watts (size is not critical; optional, if solder connections are desired)

Audiovisual Materials

- Optional – Images of exploration technologies (see Learning Procedure, Step 1c)

Teaching Time

Two or three 45-minute class periods

Seating Arrangement

Groups of two to four students

Maximum Number of Students

30

Key Words and Concepts

Ocean Exploration
Okeanos Explorer
Telepresence
Satellite communication
Wireless communication
Transmitter
Receiver

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

On August 13, 2008, the NOAA Ship *Okeanos Explorer* was commissioned as "America's Ship for Ocean Exploration;" the only U.S. ship whose sole assignment is to systematically explore Earth's largely unknown ocean. The strategy for accomplishing this mission is to use state-of-the-art technologies to search the ocean for anomalies; things that are unusual and unexpected. When an anomaly is found, the exploration strategy shifts to obtaining more detailed information about the anomaly and the surrounding area. An important concept underlying this strategy is the distinction between exploration and research. As a ship of discovery, the role of *Okeanos Explorer* is to locate new features in the deep ocean, and conduct preliminary investigations that provide enough data to justify follow-up by future expeditions.

The *Okeanos Explorer* strategy involves three major activities:

- Underway reconnaissance;
- Water column exploration; and
- Site characterization.

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site:
http://oceanexplorer.noaa.gov/okeanos/welcome.html

Okeanos Explorer Vital Statistics:

Commissioned: August 13, 2008; Seattle, Washington
Length: 224 feet
Breadth: 43 feet
Draft: 15 feet
Displacement: 2,298.3 metric tons
Berthing: 46, including crew and mission support
Operations: Ship crewed by NOAA Commissioned Officer Corps and civilians through NOAA's Office of Marine and Aviation Operations (OMAO); Mission equipment operated by NOAA's Office of Ocean Exploration and Research

For more information, visit *http://oceanexplorer.noaa.gov/okeanos/welcome.html*.
Follow voyages of America's ship for ocean exploration with the *Okeanos Explorer* Atlas at *http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm*

Underway reconnaissance involves mapping the ocean floor and water column while the ship is underway, and using other sensors to measure chemical and physical properties of seawater. Water column exploration involves making measurements of chemical and physical properties "from top to bottom" while the ship is stopped. In some cases these measurements may be made routinely at pre-selected locations, while in other cases they may be made to decide whether an area with suspected anomalies should be more thoroughly investigated. Site characterization involves more detailed exploration of a specific region, including obtaining high quality imagery, making measurements of chemical and physical seawater properties, and obtaining appropriate samples.

In addition to state-of-the-art navigation and ship operation equipment, this strategy depends upon four types of technology:

- Telepresence;
- Multibeam sonar mapping;
- CTD (an instrument that measures conductivity, temperature, and depth) and other electronic sensors to measure chemical and physical seawater properties; and
- A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery and samples in depths as great as 4,000 meters.

In many ways, telepresence is the key to the *Okeanos Explorer*'s exploration strategy. This technology allows people to observe and interact with events at a remote location. The *Okeanos Explorer*'s telepresence capability is based on advanced broadband satellite communication through which live images can be transmitted from the seafloor to scientists ashore, classrooms, and newsrooms, and opens new educational opportunities that are a major part of *Okeanos Explorer*'s mission for advancement of knowledge.

Map showing the Coral Triangle region – the most diverse and biologically complex marine ecosystem on the planet. The Coral Triangle covers 5.7 million square km, and matches the species richness and diversity of the Amazon rainforest. Although much of the diversity within the Coral Triangle is known, most still remains unknown and undocumented. Image courtesy of *www.reefbase.org*. *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/coral_triangle_hires.jpg*

In the summer of 2010, years of planning, field trials, and state-of-the-art technology came together for the first time on the the ship's maiden voyage as part of the INDEX-SATAL 2010 Expedition. This expedition was an international collaboration between scientists from the United States and Indonesia to explore the deep ocean in the Sangihe Talaud Region. This region is located in the 'Coral Triangle', which is the global heart of shallow-water marine biodiversity. A major objective of the expedition was to advance our understanding of undersea ecosystems, particularly those associated with submarine volcanoes and hydrothermal vents. Among the Expedition's many "firsts," this was the first time scientists have been able to use an underwater robot to get a first-hand look at deepwater biodiversity in the waters of the Sangihe Talaud Region. For more information about the INDEX-SATAL 2010 Expedition, see *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*.

Thanks to telepresence, these experiences were not confined to a few scientists aboard the *Okeanos Explorer*. Video from the underwater robot was transmitted to a satellite orbiting in a fixed position above Earth, then was relayed to the University of Rhode Island's Inner Space Center. From there, video and audio from the ship was sent to other Exploration Command Centers (ECCs) in Seattle, New Hampshire, Maryland, Connecticut, and Indonesia. Observers in these ECCs were able to communicate with the *Okeanos Explorer*'s Control Room via the Internet. At first, only computers connected to the advanced academic network called Internet2 were able to view the video,

> "but as the excitement built up around the *Okeanos Explorer* and the INDEX-SATAL Expedition, participants began using increasingly creative solutions for developing ad-hoc viewing stations and in some cases mini-ECCs utilizing the standard Internet. These solutions extended telepresence capabilities to smaller academic institutions, public venues, hotel rooms, the cafeteria at the U.S. Embassy in Jakarta, and even at one scientist's private residence."

This quotation is from "Implementing Telepresence: Technology Knows No Bounds," INDEX-SATAL 2010 daily log for July 9, 2010 by Webb Pinner and Kelley Elliott; *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july09/july09.html*.

This lesson guides an introduction to ocean exploration aboard the *Okeanos Explorer*, and how the concept of telepresence is implemented as part of the overall exploration strategy.

Learning Procedure

NOTE:

This lesson is intended to provide an introduction to some of the fundamental concepts that provide the foundation for wireless communication technology, as well as opportunities to integrate technology and engineering content with core science and mathematics curricula. Depending upon curriculum mandates and the availability of time and resources, this introduction may be extended to include additional content and activities described in the American Radio Relay League's *Education and Technology Curriculum Guide* and *Radio Lab Handbook* available as free downloads from *http://www.arrl.org/curriculum-guide* and *http://www.arrl.org/radio-lab-handbook*, respectively.

1. To prepare for this lesson:
   a) Review:
      - Introductory essays for the INDEX-SATAL 2010 Expedition (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*);
      - "Executing Telepresence: The Seattle ECC Comes Online!" by Kelley Elliott and David Butterfield (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/june29/june29.html*);

All communications with the shore are made possible by the *Okeanos Explorer*'s powerful satellite dome, which enables the ship to establish high-bandwidth connectivity with Exploration Command Centers throughout the world. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010 *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/okeanos_vsat_hires.jpg*

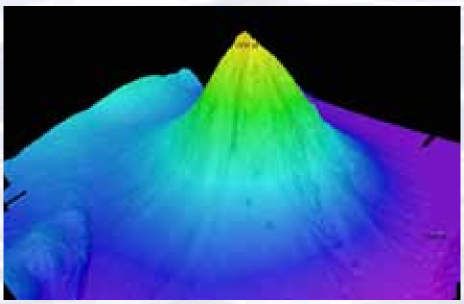
Satellite Communications Aboard the *Okeanos Explorer*

The most prominent piece of communications equipment aboard *Okeanos Explorer* is the 4.2 m diameter dome that houses the ship's 3.7 meter Very Small Aperture Terminal (VSAT) dish antenna. This antenna is the critical link between the *Okeanos Explorer* and the satellites that relay information between the ship and shore-based Exploration Command Centers, as well as NOAA's Network Operations Center.

Computers and hardware included in the antenna system make constant adjustments that compensate for the ship's heave, roll and pitch to keep the antenna pointed toward the appropriate communications satellite. Radio transmitters and receivers connected to the VSAT antenna operate in the global C-band, using frequencies between 3.7 to 4.2 GHz for downlinks, and frequencies between 5.925 GHz to 6.425 GHz for uplinks (signals received from a satellite are downlinks; signals sent to a satellite are uplinks). These frequencies are in the microwave region of the electromagnetic spectrum.

The satellites used by the *Okeanos Explorer*'s telepresence system are 22,753.2 statute miles ("normal" miles, not nautical miles) above Earth's surface. At this altitude, the satellites' rotational speed matches the speed of Earth's rotation so they appear to remain in a fixed position when viewed from Earth's surface. For this reason, these satellites are called "geo-synchronous" or "geo-stationary".

The ROV Little Hercules descends through deep water to an undersea volcano in the Celebes Sea to search for hydrothermal vents and associated ecosystems. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/1june29_hires.jpg



Okeanos Explorer's EM302 multibeam sonar mapping system produced this detailed image of the Kawio Barat seamount, which rises around 3800 meters from the seafloor. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/june26fig1_hires.jpg

Scientists in the Exploration Command Center at NOAA's Pacific Marine Environmental Laboratory in Seattle view live video from the *Okeanos Explorer's* ROV. Image courtesy NOAA
http://www.pmel.noaa.gov/images/headlines/ecc.jpg

Senior Survey Technician Elaine Stuart holds onto the CTD as it comes aboard the *Okeanos Explorer*. Image courtesy NOAA
http://www.moc.noaa.gov/oe/visitor/photos/photospage-b/CAP%20015.jpg

- "Implementing Telepresence: Technology Knows No Bounds" by Webb Pinner and Kelley Elliott (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july09/july09.html*); and

b) Review background information about the *Okeanos Explorer* exploration strategy and technologies.
(c) If desired, download images to accompany discussions in Step 2.
(d) Review procedures for Hands-On Activity Guides referenced in Step 4, and decide whether these will be included with this lesson.

2. Briefly introduce the NOAA Ship *Okeanos Explorer* and the INDEX-SATAL 2010 Expedition. Briefly discuss why this kind of exploration is important (for background information, please see the lesson, *Earth's Ocean is 95% Unexplored: So What?*; *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/so_what.pdf*). Highlight the overall exploration strategy used by *Okeanos Explorer*, including the following points:
   - The overall strategy is based on finding anomalies;
   - This strategy involves
     - Underway reconnaissance;
     - Water column exploration; and
     - Site characterization;
   - This strategy relies on four key technologies:
     - Multibeam sonar mapping system;
     - CTD and other electronic sensors to measure chemical and physical seawater properties;
     - A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery and samples in depths as great as 4,000 meters; and
     - Telepresence technologies that allow people to observe and interact with events at a remote location.

   You may want to show some or all of the images in the adjacent sidebar to accompany this review.

   Ask students why telepresence is important to ocean exploration. In addition to making it possible for more people to interact in real time with events aboard the *Okeanos Explorer*, students should realize that communication is essential to the scientific process, which is based on the idea of testing hypotheses, then reporting the results to others who can verify those results or find additional information that builds on them. For this reason, it is critical for scientific communications to convey accurate information.

   Show students the well-known statement: "I know you believe you understood what you think I said, but I'm not sure you realize that what you heard is not what I meant to say." This statement is often used to highlight the difficulties of human communication. Ask students to describe the basic process of human communication, beginning with an idea that one person wishes to convey to another. Students should recognize that the person with the idea (the sender) translates the idea into words, symbols, pictures, or some other form outside the sender's brain; then the sender gives this translation to the person intended to receive the idea; and finally the receiver translates the words, symbols, or other information received back into an idea. If all goes well, the idea that ends up in the receiver's brain is the same as the idea that originated in the sender's brain; but there are many things that can go wrong.

The impact of telepresence is marvelous: 10-20 scientists and thousands of public onlookers from three countries, five time zones, and distributed across thousands of miles, are able to witness, discuss and document the incredible life and habitats existing at the bottom of Indonesia's deep ocean. Here, participants view images sent from the bottom of the ocean off Indonesia to monitors at the Exploration Command Center in Seattle. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/seattle_command_center_hires.jpg

An obvious possible problem is that the sender and receiver may not attach exactly the same meaning to the symbols used to convey the idea. The potential for this problem increases when different languages are involved. Ask students what could be done to find out whether the idea has been successfully communicated. An obvious solution is to have the receiver repeat the idea back to the sender, who can then compare the receiver's version with the original. This is a feedback process; simple and effective, but often unused in human communications. Air traffic controllers, on the other hand, are required to use a feedback mechanism called a readback/hearback loop to verify that information has been accurately communicated.

Briefly discuss other factors that can influence the effectiveness of human communication. These factors include distractions, moods, prejudice, experience, physical well-being, and many others. A major influence is that humans communicate in multiple ways at the same time. In fact, it is almost impossible NOT to communicate, whether we want to or not; gestures, appearance, tone of voice, and even absence can all send signals to others that may conflict with our conscious efforts to directly communicate ideas. The importance of "body language" is often mentioned in this context, and may be much more significant than verbal communication in determining the message that is actually received. In many cases, it seems that we listen best through our eyes.

Return to the question of how telepresence contributes to scientific communication. Students should recognize that
- Telepresence makes visual communication possible, which greatly enhances the transfer of information and ideas;
- Telepresence provides the opportunity for feedback, to verify the accuracy of information received; and
- Telepresence greatly shortens the time required for the "scientific feedback" process to occur by allowing more people to interact with exploration activities in real time.

3. Tell students that their assignment is to investigate the basic technology that makes telepresence possible. Provide each student or student group with a copy of the "Wireless Communications Worksheet." When students have finished answering Worksheet questions, lead a discussion of their results. The following points should be included:

Question 1:

Wireless communication literally means communicating without wires. This definition could include smoke signals, drums, and ordinary human speech. Normally, however, this term refers to techniques for communicating over long distances using electromagnetic waves, as opposed to techniques that require wires to connect a sender with a receiver.

Question 2:

- Hans Christian Ørsted demonstrated that an electric current produces a magnetic field as it flows through a wire.

- Michael Faraday created the first electric motor based on Ørsted's observation. He also showed that a magnet moving through a loop of wire caused an electric current to flow in the wire, and that a current also flowed if the loop was moved over a stationary magnet.

- In 1864, James Clerk Maxwell predicted the existence of electromagnetic fields, and that these fields are responsible for electricity, magnetism and light. He also predicted that electric and magnetic fields travel through space in the form of waves at the speed of light.

- Heinrich Rudolf Hertz validated Maxwell's predictions with experiments between 1886 and 1888, but saw no practical use for his discoveries.

- Nikola Tesla began researching electromagnetic fields in 1891, and demonstrated numerous inventions that could be considered the forerunners of wireless communications. Between 1895 and 1898, he received wireless signals transmitted via short distances and demonstrated a radio controlled boat.

- Guglielmo Marconi built on the discoveries of Hertz and possibly Tesla to develop wireless communications systems. In 1897 he received a British patent for a radio based on designs and techniques of several other experimenters, including Tesla. By 1899, Marconi had demonstrated the effectiveness of wireless telegraph communications between ships and shore stations, and in 1899 transmitted the first wireless message across the English Channel, and later established the first transatlantic radio service.

- Reginald Fessenden began working with Thomas Edison in 1886, and developed a wireless telephone communication system that was operating between Pittsburgh and Allegheny City by 1899. A year later, he made the first successful wireless voice transmission.

The key point is that the development of wireless communication took place in many steps, and involved many individuals who advanced understanding so that others could build on their results. Students may also note that it is quite possible that some individuals (e.g., Tesla) may deserve more credit than is commonly understood.

Question 3:

Some wireless communication devices that are commonly used by students include:

- Cell phones;
- Wireless Internet;
- Remote controls for televisions, media players, and other appliances;
- Satellite television;
- Car radios;
- Global positioning systems;
- Garage door openers;
- Keyless locks and entry systems (also called RFID systems, which stands for radio frequency identification).

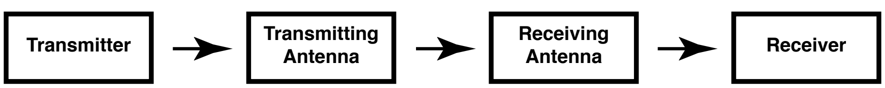
Question 4:

Students should realize that neither the transatlantic cable nor modern wireless technology have caused "old prejudices and hostilities" to cease to exist. Building on earlier discussions about human communication (Step 2) students should understand that the ability to exchange signals does not necessarily mean that these signals will be understood, nor that the signals will convey the same meaning to sender and receiver. Many of the same factors that interfere with one-on-one human communication (prejudice, mood, external influences, etc.) also interfere with cultural communications that might lessen old prejudices and hostilities.

Question 5:

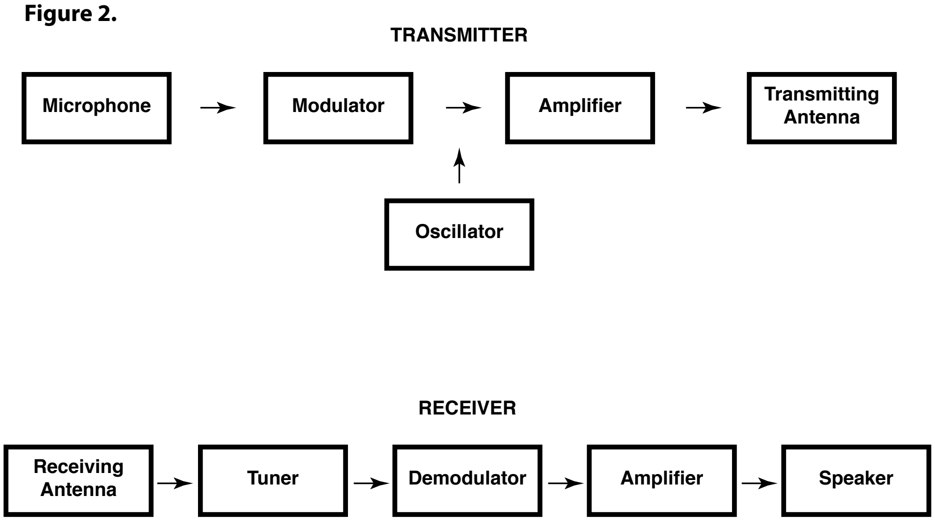
The simplest acceptable block diagram of a wireless system should include a transmitter, transmitting antenna, receiving antenna, and receiver (Figure 1).

Figure 1.



A satellite is not needed to cover a distance of 100 miles, though a satellite might improve the quality of the communication. A better diagram will include some more details about the transmitter and receiver (Figure 2):

Figure 2.



In Figure 2, the modulator in the transmitter encodes the audio signal from the microphone onto the radio frequency wave produced by the oscillator (modulation can be done several ways; see "A Day in the Life of an Ocean Explorer for a demonstration). The strength of the radio frequency wave is boosted by the amplifier. The amplified signal is sent to the antenna, which radiates the radio frequency energy. The antenna may radiate the energy in all directions, or it may radiate in a narrower direction so that more energy is sent toward the receiver. At the receiver, the tuner is set to match the frequency of the radio wave sent by the transmitter. The antenna receives some of the energy from the transmitted wave, and sends the signal through a demodulator that extracts the audio signal from the radio frequency wave. The audio signal is amplified, and sent to a speaker which makes the signal audible to humans. For more information, see the American Radio Relay League's "Radio Lab Handbook;" *http://www.arrl.org/radio-lab-handbook*.

Ask students what modifications would be needed to make this a two-way system. Students should realize the the entire system in Figure 1 would have to be duplicated, so that each station includes a transmitter as well as a receiver. Usually, the same antenna can be used to send and receive.

Tell students that communicating by wireless over 100 miles is one thing, but suppose the sending and receiving stations are thousands of miles apart. Students will probably identify the need for satellites that can relay signals between the two stations. This means that the satellite also must have a transmitter and a receiver. In each case, it is desirable for the transmitter to send the strongest signal possible, and for the receiver to be able to detect the weakest signal possible.

4. Optional – Have students complete the *Make the Simplest Radio Hands-On Activity*. You may also want to consider using one of the other activities related to wireless communications:
   - *Light Beam Modulation* (included with the *A Day in the Life of an Ocean Explorer* lesson); and
   - *Listen to Satellites* (included with the *Wow, That Hertz!* lesson).

   When students have finished building their radios, lead a discussion to summarize the relevance of this activity to telepresence aboard the *Okeanos Explorer*. Students should realize that crystal set radios are the most basic ("bare bones") demonstration of the principles that underlie wireless communication technology:
   - Radio waves strike an antenna and cause an electric current to flow in the antenna;
   - The antenna can be connected to a circuit that only allows current to flow when the radio waves have a certain frequency;
   - Radio waves that have been modulated can carry information such as audio signals;
   - The current produced by radio waves striking an antenna retains the effects of modulation, and this current also carries the information contained in the radio waves; and
   - Energy in the electric current from radio waves can be converted to sound energy that replicates the audio signals that were originally used to modulate the radio waves.

Students should also realize that modern wireless communication technology and telepresence use these same principles, but the equipment is much more complex at every stage. Amplifiers are used to increase the strength of radio waves before they are transmitted, as well as after they are received. Different types of modulation are used that can carry more information and ensure that the signals that are received match those that were sent. Specially designed antennas are used to focus radio waves in a specific direction, and to receive radio waves from a specific source. The ability to send high-resolution images and large amounts of scientific data from the *Okeanos Explorer* to the other side of the world in a few seconds requires thousands of resistors, capacitors, coils, and many other components. Still, every phone call from crew members to friends ashore, every email, and every image received in an ECC is made possible by the basic principles seen in the crystal set radio.

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science Topics" in the menu on the left side of the page, then "Human Activities," then click on "Technology" for activities and links about satellite communications and other ocean exploration technologies.

The "Me" Connection

Have students write a short essay discussing how they might use wireless communication technology in a way that is different from the ways in which they presently use this technology.

Connections to Other Subjects

English/Language Arts, Mathematics, Social Studies

Assessment

Class discussions and students' answers to worksheet questions provide opportunities for assessment.

Extensions

1. See *Living Light* (*http://oceanexplorer.noaa.gov/explorations/09bioluminescence/background/edu/media/ds_09_livinglight.pdf*) for information about scientific communication using scientific posters.
2. Find out more about wireless communications and amateur radio: The American Radio Relay League (the national association for amateur radio) has extensive resources about wireless technology including curricula, lesson plans, free downloads, kits, and projects; see *http://www.arrl.org/etp-classroom-resources*.

Multimedia Discovery Missions

http://www.oceanexplorer.noaa.gov/edu/learning/welcome.html Click on the links to Lessons 5 and 6 for interactive multimedia presentations and Learning Activities on Chemosynthesis and Hydrothermal Vent Life and Deep-Sea Benthos.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

Earth's Ocean is 95% Unexplored: So What?
(from the INDEX-SATAL 2010 Expedition)
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/so_what.pdf

Focus: Importance of deep-ocean exploration (Grades 5-6; Life Science/Earth Science)

Students describe at least three different deep-ocean ecosystems, explain at least three reasons for exploring Earth's deep ocean, and explain at least three ways that deep-ocean ecosystems may benefit humans, and create a wall magazine to communicate scientific ideas.

Living Light

(from the Bioluminescence 2009: Living Light on the Deep Sea Floor Expedition)
http://oceanexplorer.noaa.gov/explorations/09bioluminescence/background/edu/media/ds_09_livinglight.pdf

Focus: Bioluminescence (Grades 9-12; Chemistry/Life Science)

Students explain the overall process of bioluminescence, including the role of luciferins, luciferases, and co-factors; discuss at least three phyla that include bioluminescent organisms; discuss at least three ways that bioluminescence may benefit deep-sea organisms, and give an example of at least one organism that actually receives each of the benefits discussed; and create a scientific poster to communicate technical information.

Other Resources

Anonymous. 2010. Web site for the INDEX-SATAL 2010 Expedition [Internet]. Office of Ocean Exploration and Research, NOAA [cited January 7, 2011]. Available from *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html* – Includes links to lesson plans, career connections, and other resources

Anonymous. Ocean Explorer [Internet]. NOAA Office of Ocean Exploration and Research [cited January 4, 2011]. Available from: *http://oceanexplorer.noaa.gov*.

Briggs, C. and A. Maverick, 1858. *The Story of the Telegraph and a History of the Great Atlantic Cable*. Rudd and Carleton. New York. 255 pp. Available from Google Books, *http://books.google.com/*.

DeVito, J. A. 2007. *Essentials of Human Communication* (6th Edition). Allyn & Bacon. Boston. 388 pp.

Elliott, K. and D. Butterfield 2010. Executing Telepresence: The Seattle ECC Comes Online! [Internet]. NOAA Ocean Explorer [cited January 10, 2011]. Available from: *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/june29/june29.html*

Pinner, W. and K. Elliott. 2010. Implementing Telepresence: Technology Knows No Bounds [Internet]. NOAA Ocean Explorer [cited January 10, 2011]. Available from: *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july09/july09.html*

Purwoadi, M. A. 2010. Introducing the Jakarta ECC [Internet]. NOAA Ocean Explorer [cited January 10, 2011]. Available from: *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/june25/june25.html*

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Transfer of energy

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in society

Content Standard G: History and Nature of Science
- Science as a human endeavor
- Nature of science
- History of science

Ocean Literacy Essential Principles and Fundamental Concepts

Because most Fundamental Concepts are broad in scope, some aspects of some Concepts may not be explicitly addressed in this lesson. Such aspects, however, can be easily included at the discretion of the individual educator.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

Fundamental Concept e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

Fundamental Concept g. There are deep-ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6.
The ocean and humans are inextricably interconnected.

Fundamental Concept a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.

Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Fundamental Concept c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

We value your feedback on this lesson, including how you use it in your formal/informal education settings.
Please send your comments to:
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Student Worksheet: Wireless Communications

1. What is wireless communication?

2. What did the following people contribute to the development of wireless communication technology?
   - Hans Christian Ørsted
   - Michael Faraday
   - James Clerk Maxwell
   - Heinrich Rudolf Hertz
   - Nikola Tesla
   - Guglielmo Marconi
   - Reginald Fessenden

3. List at least five wireless communication devices that you have used within the past month.

4. In 1858, the first transatlantic cable was completed. An editorial in the Times of London commented:

   > "Tomorrow the hearts of the civilized world will beat in a single pulse, and from that time forth forevermore the continental divisions of the earth will, in a measure, lose those conditions of time and distance which now mark their relations."

   Later the same year, Charles Briggs and Augustus Maverick wrote:

   > "Of all the marvelous achievements of modern science the electric telegraph is transcendentally the greatest and most serviceable to mankind. . . The whole earth will be belted with the electric current, palpitating with human thoughts and emotions. . . How potent a power, then, is the telegraphic destined to become in the civilization of the world! This binds together by a vital cord all the nations of the earth. It is impossible that old prejudices and hostilities should longer exist, while such an instrument has been created for an exchange of thought between all the nations of the earth."

   Do you think the electric telegraph and its successor, wireless communications, have produced the benefits forecast by these writers? What other factors may have been involved?

5. Draw a block diagram showing the major components needed to send a wireless voice message between two points on Earth that are 100 miles apart (you only need to show the components needed to send a message in one direction).

Hands-On Activity Guide: Make the Simplest Radio

During World War II, some soldiers listened to news and entertainment using "Foxhole Radios" that they made with some wire, a razor blade, a safety pin, and a pair of earphones. These contraptions were a type of "crystal set," the simplest type of radio, and were the first widely-used type of radio receiver. Because they use very few parts, crystal set radios provide an effective "bare bones" demonstration of the basic principles that underlie wireless communication technology.

Many crystal sets designs are available on the Internet, including an entire Web site devoted exclusively to building them (*http://www.midnightscience.com/index.html*). This Web site, operated by the Xtal Set Society, provides many relevant resources, including detailed instructions and kits of parts. The Society's Oat Box Crystal Set is easy to build and uses inexpensive and readily available parts (see *http://www.midnightscience.com/oat-box-project.html*). The following summary is adapted from the Oat Box Crystal Set manual.

Materials

150 ft - #24 insulated wire (twin-lead speaker wire may be less expensive than regular hookup wire)
1 - 1N4001 diode (*e.g.*, Radio Shack 276-1101)
1 - 100-pf disc capacitor (*e.g.*, Radio Shack 272-0123)
1 - Resistor, 47 K-ohm, 1/2- or 1/4-watt
2 - Alligator clips (*e.g.*, Radio Shack 270-380)
1 - High impedance ceramic earphone (or the amplified speaker used in the Light Beam Modulation activity included with the *A Day in the Life of an Ocean Explorer* lesson)
5 - Machine screws, 6-32 x 3/4-inch
5 - Solder lugs, #6 hole (optional, if solder connections are desired)
5 - 6-32 nuts (10 nuts if solder lugs are not used)
10 - Flat washers, #6 hole (20 washers if solder lugs are not used)
1 - Empty round oatmeal box
3 ft - Masking tape
1 ft - Solder (optional, if solder connections are desired)

- **Tools**

1 - Pair small wire cutters
1 - Awl or icepick
1 - Screwdriver to fit 6-32 machine screws
1 - Pair needle nose pliers
1 - Soldering iron; approximately 60 watts (size is not critical; optional, if solder connections are desired))

Procedure

1. If you are using the Oat Box Crystal Set manual, attach the paper template to the oat box. Otherwise, use Figures 1 and 2 as guides. Punch holes for the five machine screws using an icepick or awl.

2. Mount the five 6-32 machine screws. If you plan to use solder connections, place a flat washer on a machine screw, then push the screw through one of the holes from the inside of the oat box. Then place another washer onto the screw, followed by a solder lug, then fasten the assembly in place with a 6-32 nut.

Figure 1.

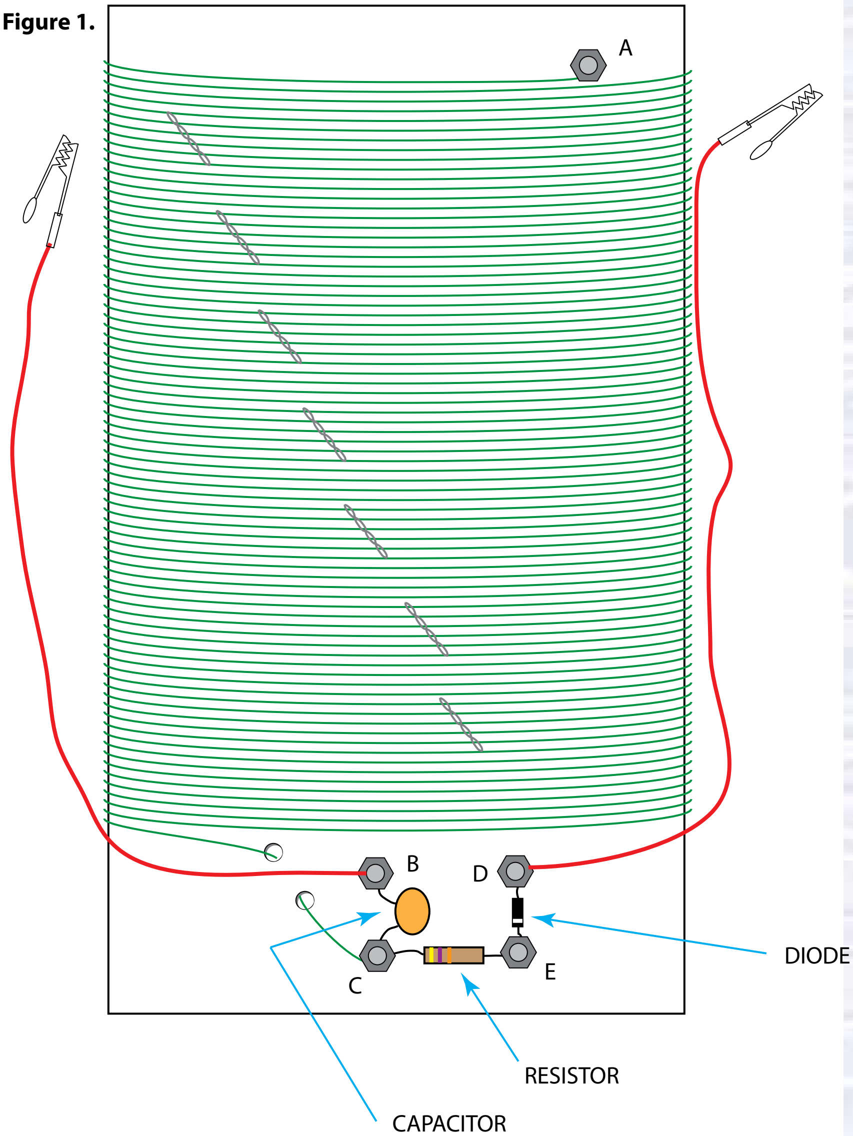
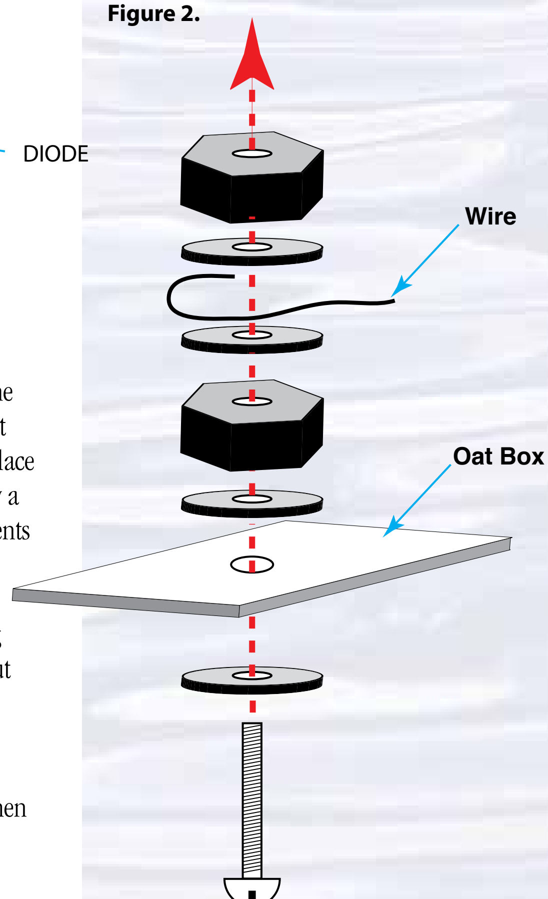


Figure 2.



If you do not plan to use solder connections, place a flat washer on a machine screw, then push the screw through one of the holes from the inside of the oat box. Then place another washer onto the screw, and fasten the assembly in place with a 6-32 nut. Place two more washers onto the machine screw followed by a second nut. Do not tighten the second nut until all of the wires and components are in place (see Figure 2).

3. Prepare eight lengths of #24 insulated wire, 128 inches long. If you are using twin-lead speaker wire, separate the two leads into single wires. Remove about 1-inch of insulation from both ends of each wire.

4. Attach one end of one wire to the machine screw near the top of the oat box, either by soldering or by wrapping the wire around the machine screw and then tightening the outside nut.

5. Wrap the wire around the oat box, keeping each coil snugly against the preceding coil. When most of the wire has been wrapped onto the oat box, tape the coil turns onto the box with masking tape. Twist the bare end of another wire together with

the bare end of the first wire, and continue wrapping the second wire around the oat box. These twists are called "taps." Leave them sticking out, because they will be used to make connections later. Continue this procedure until all eight lengths of wire have been wrapped onto the box. *TIP: Keeping the lid on the oat box will help the box keep its shape during wrapping.*

6. Punch two holes near the end of the last length of wire as shown in the manual or in Figure 1. Feed the end of the last length of wire through the nearest hole, then out of the other hole, and fasten to the machine screw labeled "C" in Figure 1. Do not solder the solder lug or tighten the second nut on this machine screw yet.

7. Prepare two 8-inch lengths of #24 insulated wire by removing about 1/2-inch of insulation from one end of each wire, and connecting each of these ends to an alligator clip. Remove about 3/4-inch of insulation from the other end of each wire. Fasten one of these wires to the machine screw labeled "B" in Figure 1, and the other wire to the machine screw labeled "D" in Figure 1. Do not solder the solder lugs or tighten the second nuts on these machine screws yet.

8. Connect one end of the 100-pf capacitor (it doesn't matter which end) to the machine screw labeled "B" in Figure 1. Solder the solder lug or tighten the second nut on the machine screw to complete the assembly on this machine screw.

9. Connect the other end of the 100-pf capacitor to the machine screw labeled "C" in Figure 1. Do not solder the solder lug or tighten the second nut on this machine screw yet.

10. Connect one end of the 47 K-ohm resistor (it doesn't matter which end) to the machine screw labeled "C" in Figure 1. Do not solder the solder lug or tighten the second nut on this machine screw yet.

11. Connect the other end of the 47 K-ohm resistor to the machine screw labeled "E" in Figure 1. Do not solder the solder lug or tighten the second nut on this machine screw yet.

12. Examine the diode and find the cathode end (usually, the end with a white band). Connect this end of the diode to the machine screw labeled "E" in Figure 1. Do not solder the solder lug or tighten the second nut on this machine screw yet.

13. Connect the other end of the diode to the machine screw labeled "D" in Figure 1. Solder the solder lug or tighten the second nut on the machine screw to complete the assembly on this machine screw.

14. Connect the earphone or leads from the amplified speaker to the machine screws labeled "C" and "E" in Figure 1. Solder the solder lugs or tighten the second nuts on the machine screws to complete the assembly on these machine screws. This completes construction of your radio!

15. Connect a wire from a cold water pipe (or other grounded object) to the machine screw labeled "C" in Figure 1. Connect about 50-feet of wire to the machine screw labeled "B" in Figure 1. The latter wire is your radio's antenna, and it should be as high as possible (but avoid getting near power lines, trying to stand on chairs,

Figure 3.

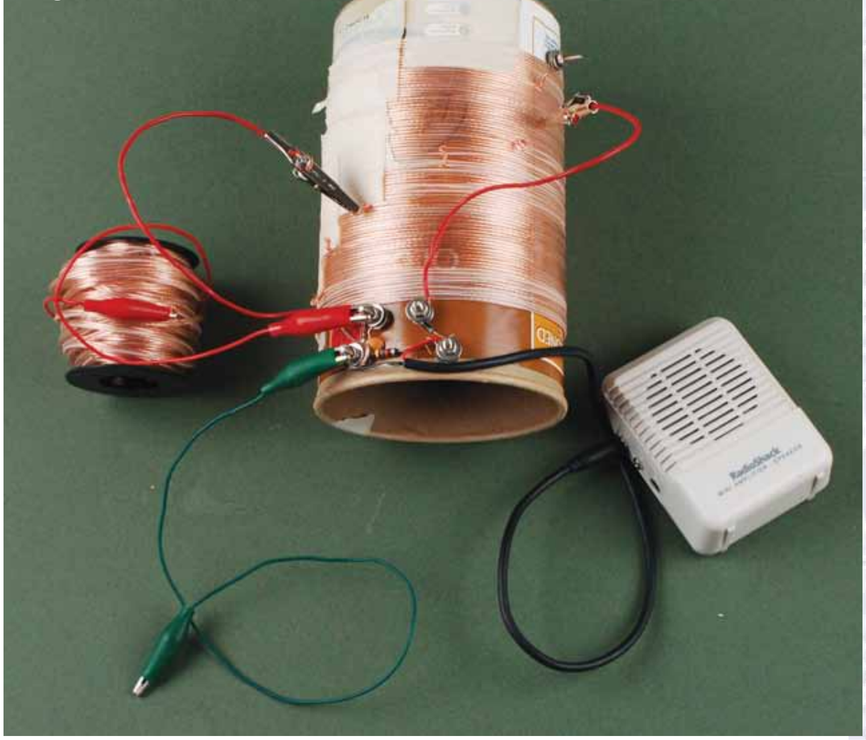


Figure 3. **A crystal radio.** Green jumper wire connects to cold water pipe (ground). Red jumper wire connects to 50-ft antenna (coiled on spool).

or unsafe use of ladders). You may use jumper cables for these connections as shown in Figure 3 to make it easy to disconnect your crystal set from the ground and antenna.

16. Attach the alligator clip from the machine screw labeled "B" in Figure 1 to the twist in the coil nearest the top of the oat box (these twists are called "taps"). Attach the alligator clip from the machine screw labeled "D" in Figure 1 to the twist in the coil to one of the taps near the center of the coil. Turn on the amplified speaker, or place the earphone in one ear.

17. Move the clip from the tap near the top of the oat box to other taps until you hear a radio station. When you have found one, move the other clip until the clearest signal is obtained.

What's Going On?

A capacitor is a device that consists of two conductors separated by an insulator. When a voltage is applied across the conductors, a static electric field develops in the insulator that stores energy. An inductor is a device that can store energy in a magnetic field created by the electric current passing through it. Inductors are usually coils of insulated wire.

When a capacitor is connected in parallel with an inductor and they are in a circuit connected to a source of alternating voltage, an alternating current will flow through the circuit. The amount of current that flows depends upon the values of capacitance and inductance in the circuit, and also upon the frequency of the applied voltage. At a certain frequency, called the resonant frequency, almost no current flows. If the frequency of the applied voltage is above or below the resonant frequency of the circuit, a much larger current will flow.

In the crystal set, the long antenna and ground act as a capacitor, and the coil is an inductor. The specific values of capacitance and inductance determine the resonant frequency of the circuit, and moving the clips from one tap to another tap changes the inductance of the coil, and consequently the resonant frequency of the circuit (because connecting to different taps essentially removes part of the coil from the circuit). This allows us to tune the radio.

We are surrounded by many electromagnetic waves of many different frequencies, including many radio waves. When radio waves strike the antenna, they causes alternating currents to flow in the radio circuit, at many different frequencies. If the frequency of a particular wave is different from the resonant frequency of the circuit, the current will flow through straight to ground, and this is what happens to most of the wave energy that enters the antenna. But if the frequency of a wave is close to the circuit's resonant frequency, most of the current will be blocked from flowing to ground, and will flow to the diode instead. Diodes are devices that allow current to flow in only one direction, so they change alternating current to direct current.

Many radio waves are modulated to contain audio information (such as music or voice communications). One way to modulate a radio wave is to vary the strength or amplitude of the wave in a pattern that matches the variations in the audio signal. This is called amplitude modulation (see the Light Beam Modulation activity included with the *A Day in the Life of an Ocean Explorer* lesson). When the current from an amplitude modulated radio wave flows through the diode, the diode changes the alternating current to a direct current whose amplitude (strength) varies because of the modulation. When this pulsing direct current flows into the earphone (or amplified speaker), the current is converted to sound energy that replicates the audio information that was originally used to modulate the radio wave before it was transmitted. In the years before diodes were invented, various mineral crystals were used instead, particularly the lead sulfide mineral known as galena.