The Physics of Cellular Telephones

Outcomes:

1. Identify questions, analyze, compile and display evidence and information to investigate the development over time of a practical problem, issue or technology. (212-3, 214-3, 115-5)
2. Explain Oersted's Principle. (328-6)
3. Analyze qualitatively and quantitatively electromagnetic induction by both a changing magnetic flux and a moving conductor. (328-7)
4. State Faraday's law of magnetic induction. (328-7)
5. Analyze and evaluate, from a variety of perspectives, using a variety of criteria, the risks and benefits to society and the environment of a particular application of scientific knowledge and technology. (118-2, 118-4)
6. Identify, analyze and describe examples where technologies were developed based on scientific understanding, their design and function as part of a community's life and science and technology related careers. (116-4, 116-6, 117-5, 117-7)

Introduction

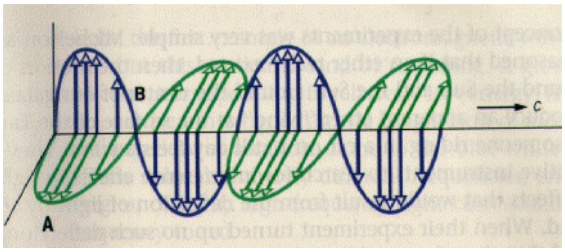
What does the name Marconi mean to you? If you live in this province, probably quite a bit. In 2001 Newfoundland and Labrador celebrated the 100th anniversary of the reception of the first transatlantic wireless message at Signal Hill by Guglielmo Marconi. This signal was sent from Poldhu, England on December 12, 1901. In the 1890's Marconi had invented and developed the wireless telegraph to send messages over large distances. At the age of twenty-seven, his success on Signal Hill marked a turning point in world-wide communication. Marconi's work laid the foundation for the development of today's cellular telephones. Marconi though, could not have imagined the enormous impact his work would have on future generations. The number of people using cellular telephones has risen dramatically during the past decade. "Experts estimate that by 2005 there will be over 1.26 billion wireless telephone users worldwide" (Cellular Telephone Use and Cancer). Neither could Marconi have imagined the possible health risks currently associated with wireless communication – risks attributed to electromagnetic fields.

Theory

Electromagnetic Fields

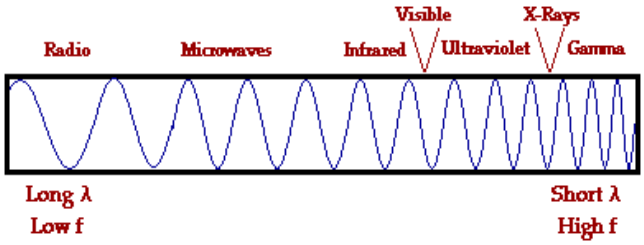
By the time you leave for school in the morning you have already been exposed to a number of electromagnetic fields – from your blow dryer to your toaster to your microwave. What are these electromagnetic fields and where do they come from? A 'field' exists in a region of space surrounding an object. We cannot necessarily see a field, but we can observe the effects of its presence. A dropped object, for example, is drawn towards the earth because of the pull of the earth's gravitational field. Oersted found that a magnetic field is produced around a wire carrying an electric current. Faraday found conversely that an electric field is induced by a changing magnetic field. Maxwell extended Faraday's and Oersted's work by hypothesizing that a *changing* electric field would also produce a magnetic field. Maxwell went on to say that if a changing magnetic field produces an electric field, that electric field is itself changing. This changing electric field would then produce a changing magnetic field, and so on. The net result of the interaction of these changing fields was a 'wave' of electric and magnetic fields travelling

through space. These waves are called electromagnetic waves. They are transverse waves where the electric and magnetic fields are perpendicular to each other and to the direction of travel.



At point A the electric and magnetic fields associated with the wave are at maximum strength and at point B the fields are at minimum strength.

Electromagnetic waves are waves of fields, not of matter as are water waves. It is because they are fields that electromagnetic waves can travel in empty space at the speed of light. It is interesting to note that Heinrich Hertz did not experimentally detect electromagnetic waves until 1887 – eight years after Maxwell's death. Electromagnetic waves have since been detected over a wide range of frequencies known as the electromagnetic spectrum.



Radio frequency (RF) radiation is one of the several types of electromagnetic radiation. It is the type of radiation emitted by cellular telephones.

Cellular Telephones and Electromagnetic Radiation

There are many different types of cellular telephones available to consumers. They all convert voice into impulses that are transmitted over radio waves at frequencies ranging from about 800 to 2100 megahertz. Moving charges in the transmitting radio antenna create electromagnetic waves that radiate away from the antenna (and can be picked up by a receiving antenna). All cellular telephones emit non-ionizing radio frequency radiation. This is different from ionizing radiation produced by X-ray machines, which can present a health risk at certain doses. According to the National Cancer Institute, the level of exposure to radio frequency radiation depends on the amount of cellular telephone traffic, the quality of transmission; how far the antenna is extended, and the size of the handset.

The main source of radio frequency energy is the cell phone antenna. The closer the antenna is to the head, the higher the exposure to radio frequency radiation. The intensity of the electromagnetic wave actually changes as $\frac{1}{r^2}$ (where represents distance). The antenna would be closest to the person's head in a hand-held cellular phone since the antenna is actually in the handset.

The intensity of the radio frequency radiation also depends on the power level of the signal sent to and from the nearest base station. Each zone in a particular geographic region has its own base station. When a call is made from a cell phone, a signal is sent to this base station. The base station then sends the call through a switching center where it is transferred to another base station, another cell phone or to the local land line system. The farther a cell phone user is from the base station, the more power is required to maintain the connection. This will increase the amount of radio frequency radiation for the user. It should also be noted that digital phones (which operate at different frequencies and power levels) are believed to emit less radiation than the older analog versions.

Health Risks

"Amazing, fast-paced, ever-evolving technology is progress. But progress often comes with a price. The price might be negative effects on our health" (Cell Phones and Electromagnetic Health Hazards). Recently there has been concern that the use of cell phones (particularly hand-held models) may be linked with loss of memory, Parkinson's disease, headaches and even cancer. This concern has prompted several studies, particularly on the link between cell phone use and cancer. Overall, most of these studies do not support such a link. However, based on the fact that cellular telephones have been available for a relatively short period of time, it

would be premature to conclude that there is no link between cellular telephone use and cancer. It is important to continue the research, addressing the effects of long-term cell phone use as well as the differences between analog and digital technologies. Slesin (2002) notes that a, "lack of studies about the adverse effects of EMF's may also prevent us from finding beneficial effects" (p. 2). In the meantime, preventative measures can be taken at least regarding cell phone use. Consumers can purchase a device called a 'Wave Buster' which claims to absorb up to seventy percent of electromagnetic fields from cell phones (due to its ceramic composition). The Wave Buster has two pieces – one that attaches near the antenna and the other over the speaker. In the absence of such a device, users can limit cell phone use or switch to a phone with a headset where there is more distance between the antenna and the user. It is your responsibility to take EMF exposure into your own hands. "As more evidence uncovers the truth about EMF's, it's prudent to protect you and your family, while enjoying all that technology has to offer" (Cell Phones and Electromagnetic Health Hazards, p. 2).

Conclusion

Electromagnetic fields surround us constantly – whether they be from cell phones or microwaves or television sets. Moreover, the number of EMF sources are growing rapidly. Unfortunately "the entire effect of multiple electromagnetic fields on human physiology is not completely understood" (Electromagnetic Fields and your Health). Since the adverse effects of exposure to EMF's appear to arise slowly, the consequences of living in a world filled with EMF's may not be known for many years. Until then we can only continue the exploration begun in part by Marconi.

Questions

1. What is an electromagnetic wave?
2. An electromagnetic field is measured at a distance 'r' away from the source. How will the electromagnetic field change at a distance '$2r$' from the source?
3. What is the difference between ionizing and non-ionizing radiation?
4. **Research:** What are some other kinds of electromagnetic radiation?
5. **Research:** How does the digital cellular telephone differ from the analog phone?

References

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Activities

Activity 1: (taken from Deley, 2002)

Purpose: To measure electromagnetic fields in the home.

Materials: Gaussmeter

Background: Electromagnetic radiation is measured in Gauss or milligauss. Deley states that people living in urban areas average 3 milligauss while those in rural areas average 1 milligauss. Generally, electromagnetic fields drop to naturally occurring levels at around 3 feet from the source (except around power lines).

Procedure:
Students will use the gaussmeter to measure the electromagnetic fields around cell phones and other home appliances. Take measurements in several different rooms and at different distances from the same object. Students could then graph electromagnetic field against distance to observe the relationship between the two.

Activity 2: Radio Wave Transmission

For a simulation and some information on how a radio wave is transmitted, go to: http://www.pbs.org/wgbh/aso/tryit/radio/.