The High Frequency Active Auroral Research Program

HAARP

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The Value and Importance of Ionospheric Research

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Background

In 1864, a Scottish mathematician named James Clerk Maxwell published a remarkable paper describing the means by which a wave consisting of electric and magnetic fields could propagate (or travel) from one place to another. Maxwell's theory of electromagnetic (EM) radiation was eventually proven correct by the German physicist, Heinrich Hertz in the late 1880's in a series of careful laboratory experiments.

It was not until the last decade of the 19th century that an Italian scientist named Guglielmo Marconi converted these theories and laboratory experiments into the first practical wireless telegraph system for which he was granted a British patent. In 1899, Marconi demonstrated his wireless communication technique across the English Channel.

In a landmark experiment on December 12, 1901, Marconi, who is often called the "Father of Wireless," demonstrated transatlantic communication by receiving a signal in St. John's Newfoundland that had been sent from Cornwall, England. Because of his pioneering work in the use of electromagnetic radiation for radio communications, Marconi was awarded the Nobel Prize in physics in 1909.

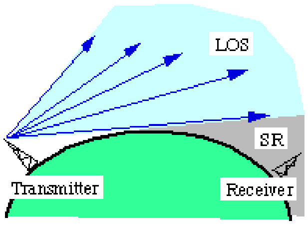

Figure 1. Areas in the light blue region are within the radio "Line of Sight" (LOS). The receiving antenna is in the shadow region (SR) and cannot receive a signal directly from the transmitter.

Marconi's famous experiment showed the way toward world wide communication, but it also raised a serious scientific dilemma. Up to this point, it had been assumed that electromagnetic radiation traveled in straight lines in a manner similar to light waves. If this were true, the maximum possible communication distance would be determined by the geometry of the path as shown in Figure 1 to the left. The radio signal would be heard up to the point where some intervening object blocked it. If there were no objects in the path, the maximum distance would be determined by the tranmitter and receiver antenna heights and by the bulge (or curvature) of the earth. Drawing from light as an analogy, this distance is often called the "Line-of-Sight" (LOS) distance. In Marconi's transatlantic demonstration, something different was happening to cause the radio waves to apparently bend around the Earth's curvature so that the communication signals from England could be heard over such an unprecedented distance.

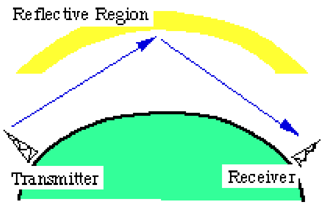

Figure 2. A conductive region at high altitude would "reflect" radio signals that reached it and return them to

In 1902, Oliver Heaviside and Arthur Kennelly each independently proposed that a conducting layer existed in the upper atmosphere that would allow a transmitted EM signal to be reflected back toward the Earth. Up to this time, there was no direct evidence of such a region and little was known about the physical or electrical properties of the Earth's upper atmosphere. If such a conductive layer existed, it would permit a dramatic extension of the "Line-of-Sight" limitation to radio communication as shown in Figure 2 to the left. During the mid-1920's, the invention of the **ionosonde** (an instrument that is an important part of the HAARP diagnostic suite) allowed direct observation of the ionosphere and permitted the first

Earth.	scientific study of its characteristics and variability and its effect on radio waves.

The excitement of Marconi's transatlantic demonstration inspired numerous private and commercial experiments to determine the ultimate capabilities of this newly discovered resource, the ionosphere. Among the most important early experiments were those conducted by radio amateurs who showed the value of the so-called high frequencies above 2 MHz for long distance propagation using the ionosphere.

The Importance of Ionospheric Research

Although our society has learned to use the properties of the ionosphere in many beneficial ways over the last century, there is still a great deal to learn about its physics, its chemical makeup and its dynamic response to solar influence. The upper portions of the ionosphere can be studied to some extent with satellites but the lower levels are below orbital altitudes while still too high to be studied using instruments carried by balloons or high flying aircraft. Much of the current theory is inferred by observing the ionosphere's effect on communication systems. In addition, some very useful information has been obtained using rockets (for example, from the Poker Flat Research Range near Fairbanks, AK). Active ionospheric research facilities, like HAARP, have provided detailed information that could not be obtained in any other way, about the dynamics and responses of the plasma making up the ionosphere. Incoherent Scatter Radars (ISRs), such as the one that will be built at the HAARP observatory, can study from the ground, small scale structures in the ionosphere to nearly the degree that an instrument in the layer could provide.

The ionosphere affects our modern society in many ways. International broadcasters such as the Voice of America (VOA) and the British Broadcasting Corporation (BBC) still use the ionosphere to **reflect** radio signals back toward the Earth so that their entertainment and information programs can be heard around the world. The ionosphere provides long range capabilities for commercial ship-to-shore communications, for trans-oceanic aircraft links, and for military communication and surveillance systems. The sun has a dominant effect on the ionosphere and solar events such as flares or coronal mass ejections can lead to worldwide communication "blackouts" on the short wave bands. We have created an Example Page with data from a communications blackout that occurred on August 3, 1997 showing how the instruments at the HAARP observatory can be used to study the underlying physics of these telecommunication disruptions.

Signals transmitted to and from satellites for communication and navigation purposes must pass **through** the ionosphere. Ionospheric irregularities, most common at equatorial latitudes (although they can occur anywhere), can have a major impact on system performance and reliability, and commercial satellite designers need to account for their effects.

In the Auroral latitudes, the ionosphere carries a current that may reach magnitudes up to or beyond a million amperes. This current, which is called the auroral electrojet, can change in dramatic ways under solar influence, and, when it does, currents can be induced in long terrestrial conductors like power lines and pipe lines. While such effects found in nature cannot be reproduced by active ionospheric research, the sensitive instruments at observatories like HAARP can follow the progress of natural magnetic storms and provide insight into the physical mechanisms at work in the ionosphere.

To varying degrees, the ionosphere is a plasma, the most common form of matter in the universe, often called the fourth state of matter. Plasmas do not exist naturally on the Earth's surface, and they are difficult to contain for laboratory study. Many current active ionospheric research programs are efforts to improve our understanding of this type of matter by studying the ionosphere, the closest naturally occurring plasma.

Recently, it has become possible to produce computer simulations of ionospheric processes. The development of computer visualizations have allowed us to see and appreciate the enormous variability and turbulence that occurs in the ionosphere during a major solar geomagnetic storm and the resultant effects that can impact radio communication and navigation systems.

Active ionospheric research facilities like HAARP attempt to produce small temporary changes in a limited region directly over the facility which, in no way, compare to the worldwide events frequently caused by the sun. But the extraordinary suite of sensitive observational instruments installed at observatories like HAARP permit a detailed and comprehensive correlation with the induced effects, resulting in new insights into the ways the ionosphere responds to a much wider variety of natural conditions.

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Pioneering Ionospheric Radio Science Research for the Twenty-First Century

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